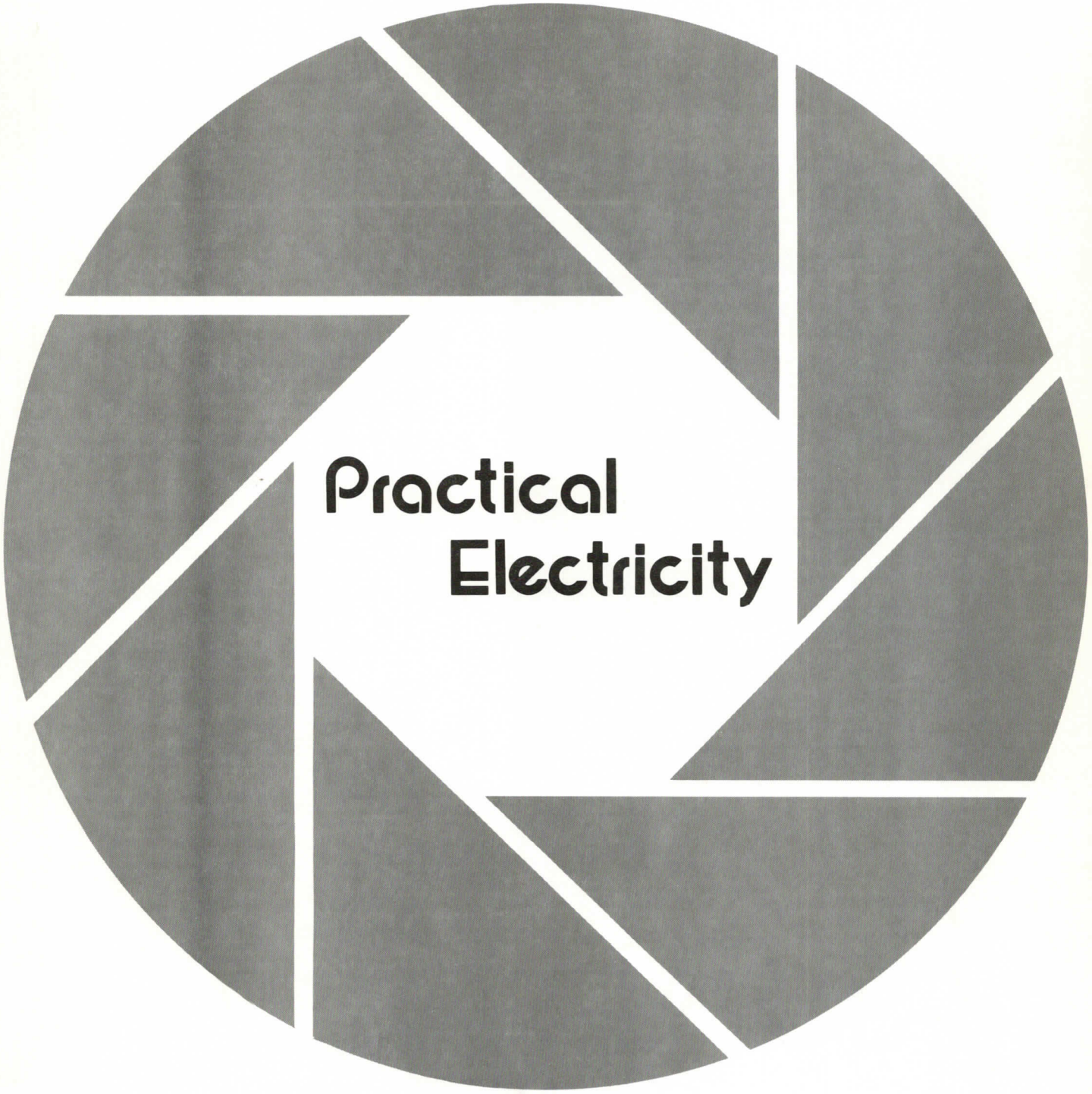
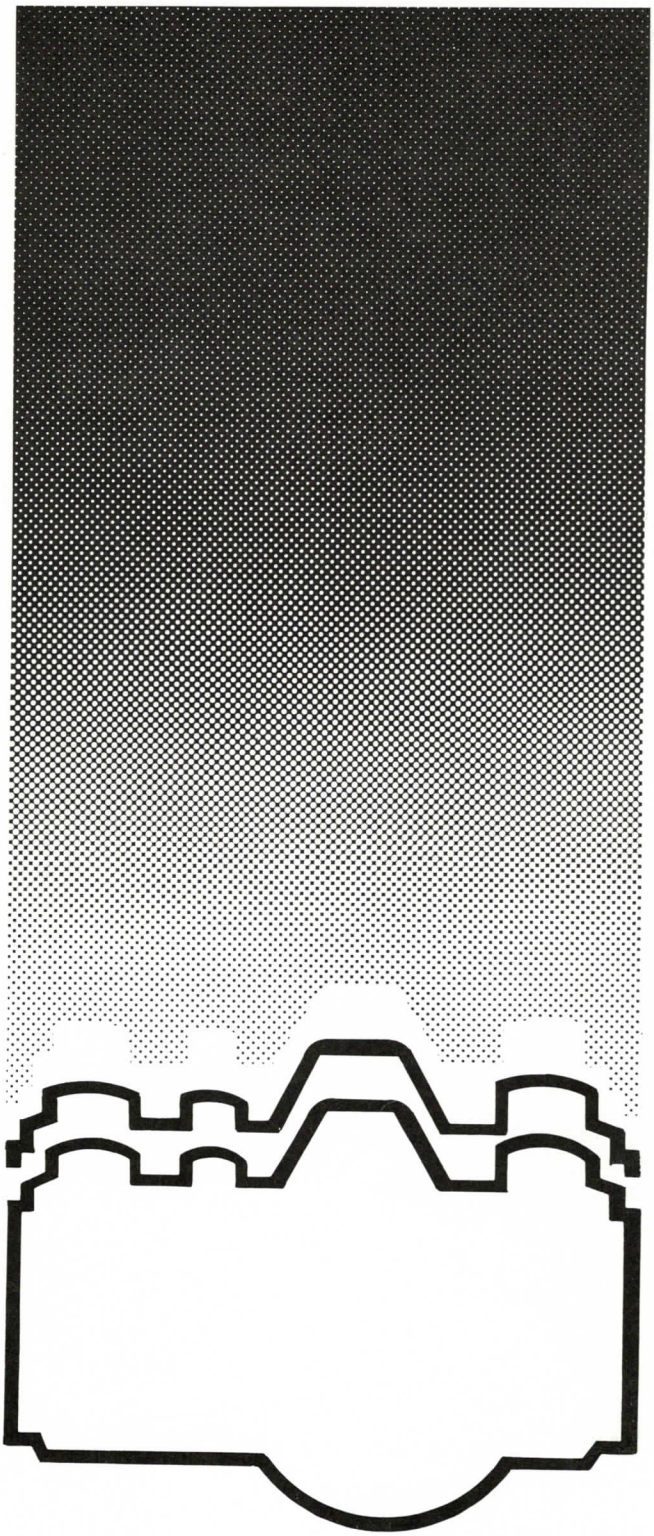

Practical
Electricity



Author
Chris Dowden

Design
Ivan Bardon

Production
Lee Van Orden

Advisory Committee

Jim Amos
Metro Camera Service

Doug Donaldson
Western Camera

Bill Glennon
Lindahl Camera

Mike Lowe
Rocky Mountain Camera Repair

Practical Electricity

contents

1 USING THE MULTIMETER
2 BE SAFETY CONSCIOUS
3 READING THE VOM
5 THE OHMMETER
6 DC VOLTMETER
6 DC AMMETER
7 AC MEASUREMENTS
9 TESTING SWITCHES
9 CLEANING SWITCHES
8 READING HIGH VOLTAGES
8 OTHER MULTIMETERS
8 TROUBLESHOOTING COMPONENTS
10 TESTING FUSES
10 TESTING RESISTORS
11 TESTING A CAPACITOR
11 TESTING A COIL
12 LAMPS
12 TESTING BATTERIES
13 RECHARGABLE BATTERIES
13 USING COMPLEX SWITCHES
15 SOLDERING
15 SELECTING A SOLDERING IRON
16 CHOOSING SOLDER
16 TINNING YOUR SOLDERING IRON
18 PREPARING A WIRE
18 TINNING A WIRE
19 PRINTED CIRCUITS AND FLEX CIRCUITS
19 DESOLDERING
20 CONNECTING WIRES

1016
©Copyright 1978
National Camera, Inc.
Technical Training Division

USING THE MULTIMETER

Due to the widespread use of electrical and electronic controls, almost every service technician in every industry relies upon the multimeter for some phase of each repair job. The multimeter is often called the VOM—a Volt-Ohm Meter. The letters VOM may also stand for Volt-Ohm Milliammeter, indicating a VOM which measures current in milliamperes. A VOM which measures current in microamperes is a Volt-Ohm Microammeter.

At the heart of the VOM is a delicate meter movement called a **galvanometer.** The galvanometer responds to changes in current through its coil by varying deflection of its needle.

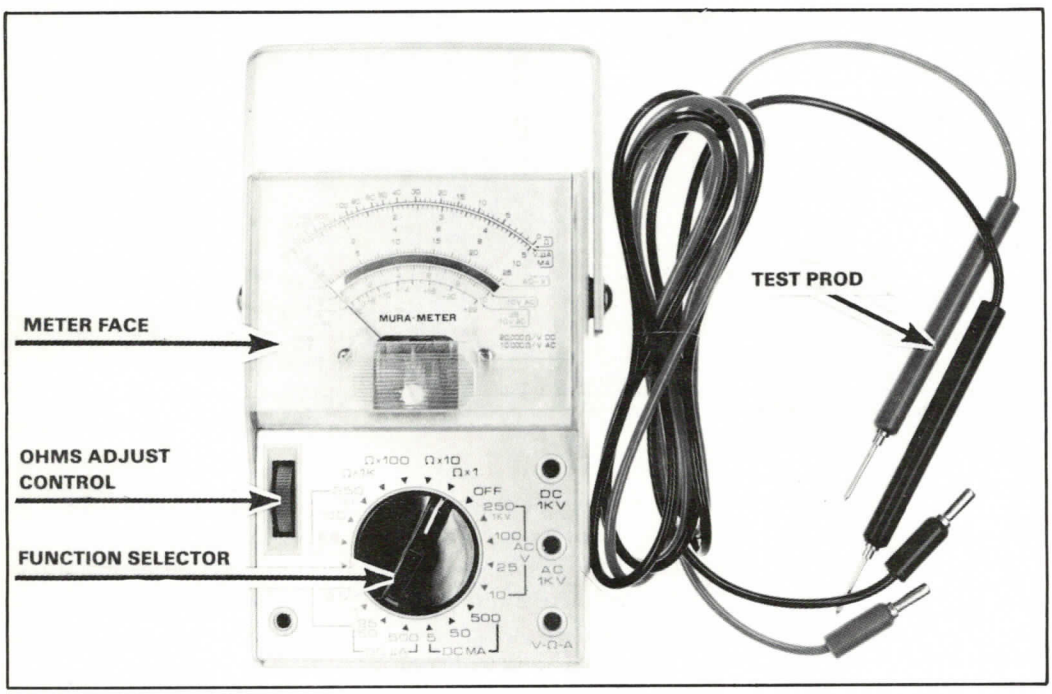


FIGURE 1 The volt-ohm milliammeter.

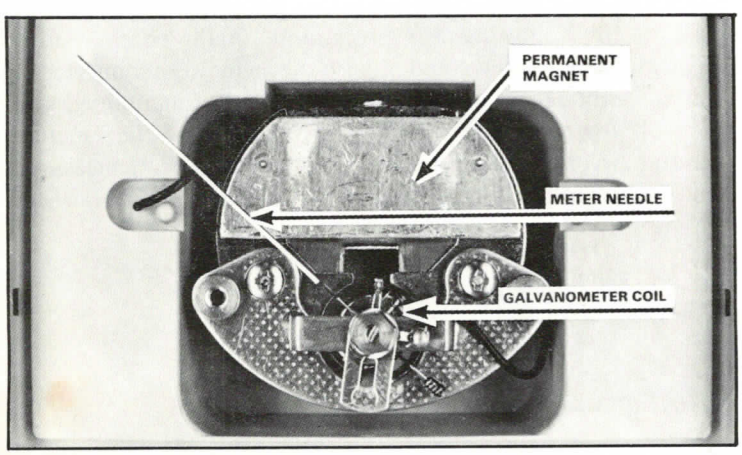


FIGURE 2 A galvanometer.

BE SAFETY CONSCIOUS

Your VOM is a rugged, reliable and accurate instrument if it's used correctly. Incorrect or careless use of your VOM will almost certainly result in its being damaged. Here are three precautions that if kept in mind will help to keep you and your VOM healthy.

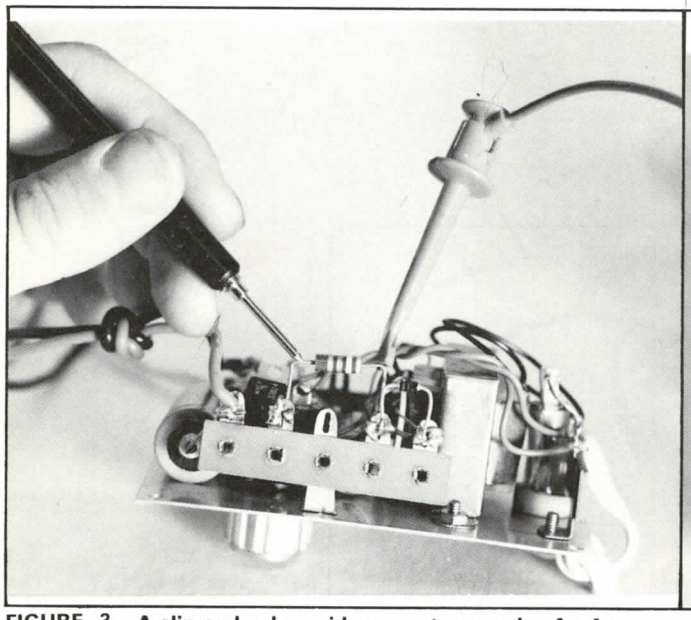


FIGURE 3 A clip-on lead provides an extra margin of safety.

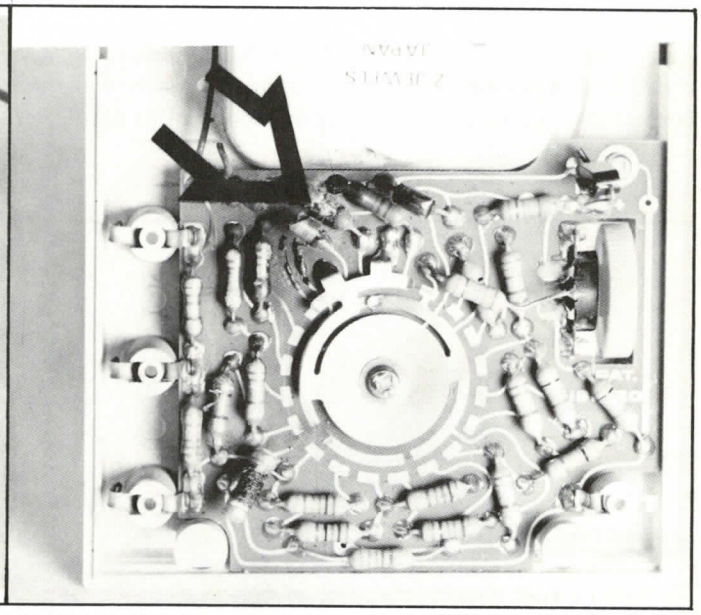
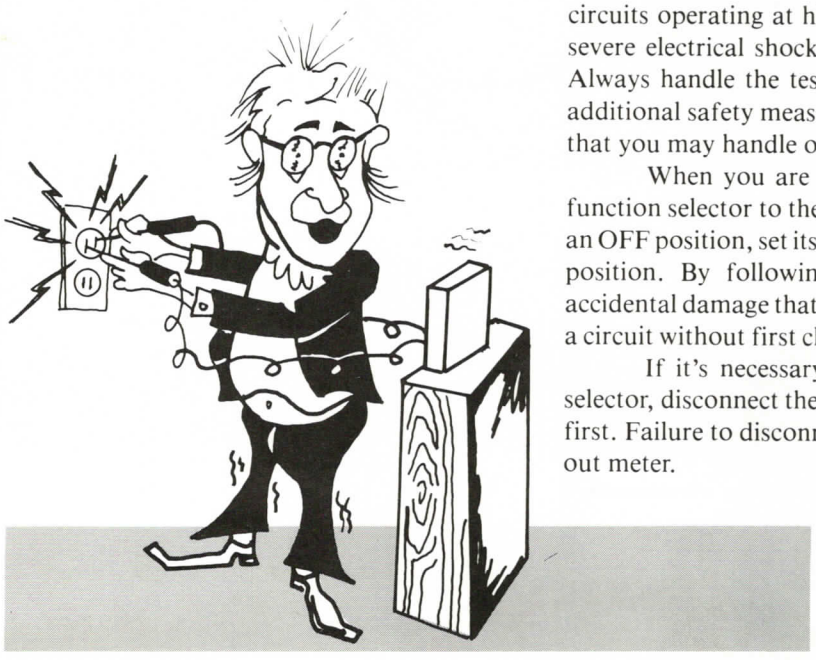


FIGURE 4 Carelessness destroyed this VOM.



You'll often use your VOM to make measurements in circuits operating at high voltages. To avoid the possibility of a severe electrical shock, ***never*** hold a test prod by its metal tip. Always handle the test prods by their plastic insulators. As an additional safety measure, you may wish to use clip-type leads so that you may handle only one meter lead at a time.

When you are through using your VOM, always set its function selector to the OFF position. If your VOM doesn't have an OFF position, set its function selector to the highest AC voltage position. By following this precaution, you'll be preventing accidental damage that could occur if the meter were connected to a circuit without first checking the setting of the function selector.

If it's necessary to change the position of the function selector, disconnect the test leads from the circuit being measured first. Failure to disconnect the test leads could result in a burned-out meter.

READING THE VOM

Most VOM's have at least three groups of scales. These groups of scales are for reading ohms, volts and amps. Many VOM's have AC volts and amps scales as well as DC volts and amps scales. Often for amps and volts there are several scales on the meter face to make obtaining an exact reading easier. Notice how the scales on a typical meter face are arranged.

In addition to the meter scales, notice that the meter we're using as an illustration has a small mirrored band on its face. The purpose of the mirrored band is to keep the meter from being read at an angle. When you read the meter, the needle should always be in line with its reflection. If you see the needle and its reflection, you'll be introducing a parallax error that will make your reading inaccurate.

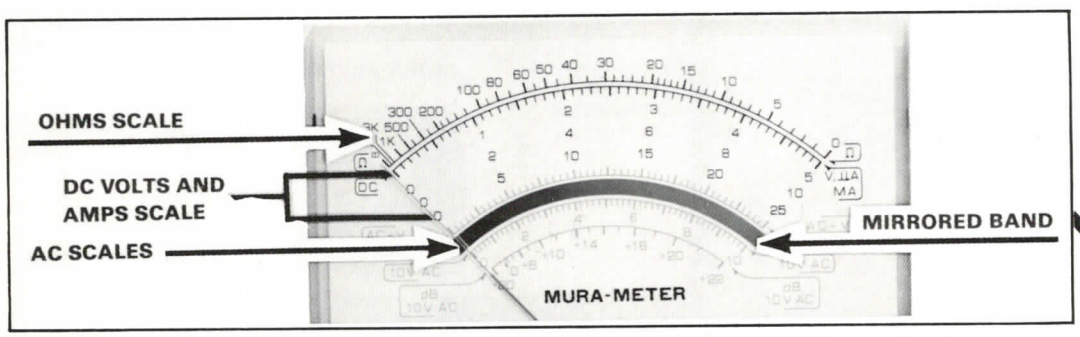


FIGURE 5

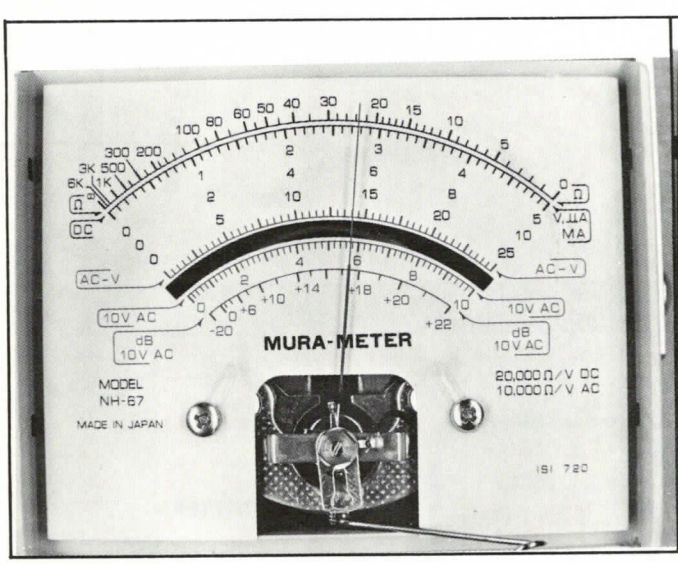


FIGURE 6 **No parallax error.**

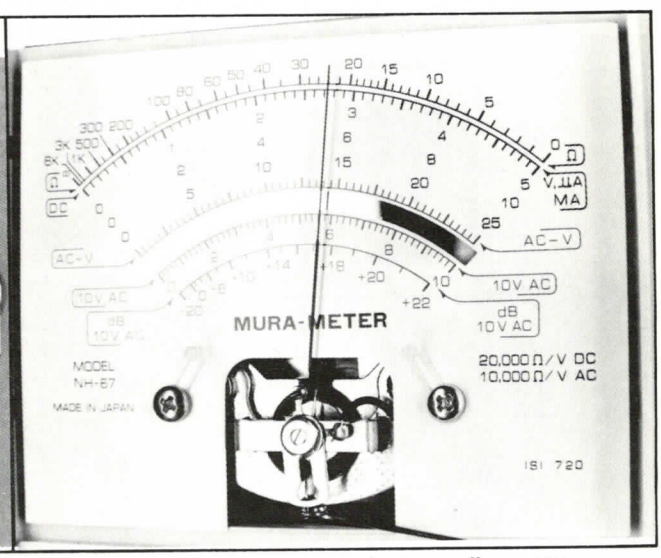


FIGURE 7 **Parallax error causes meter reading error.**

Most meters will use an arrangement of scales similar to the one shown here. Many meters have their AC scales printed in red and their DC scales printed in black to make rapid reading of the meter easy. Each scale on the meter face corresponds to a portion of the meter's **function selector.**

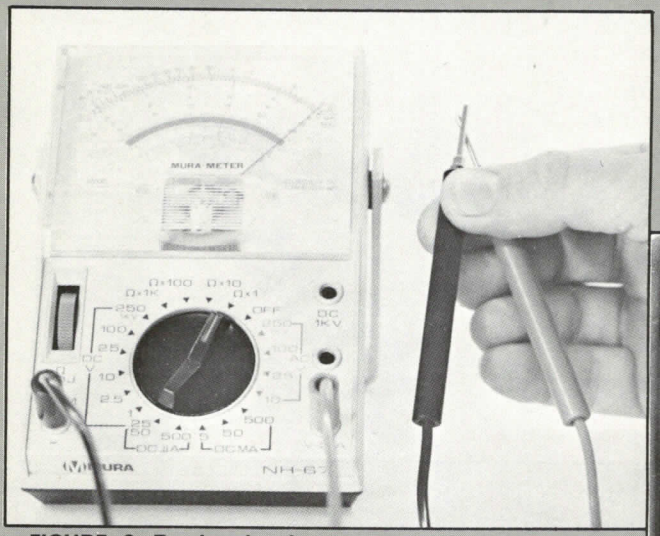


FIGURE 8 Zeroing the ohmmeter.

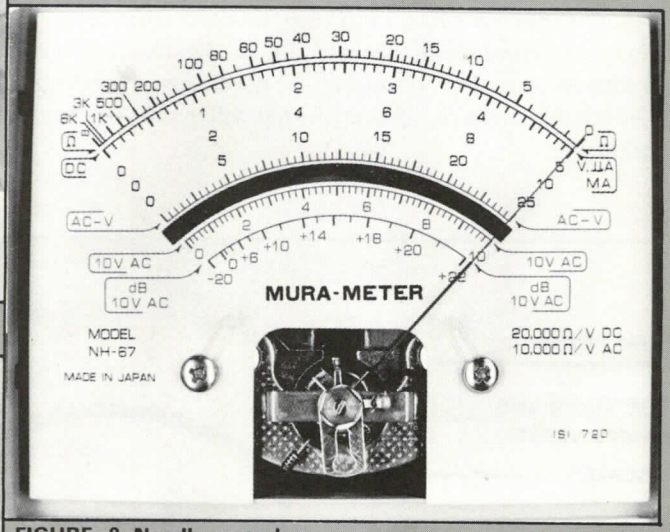


FIGURE 9 Needle zeroed.

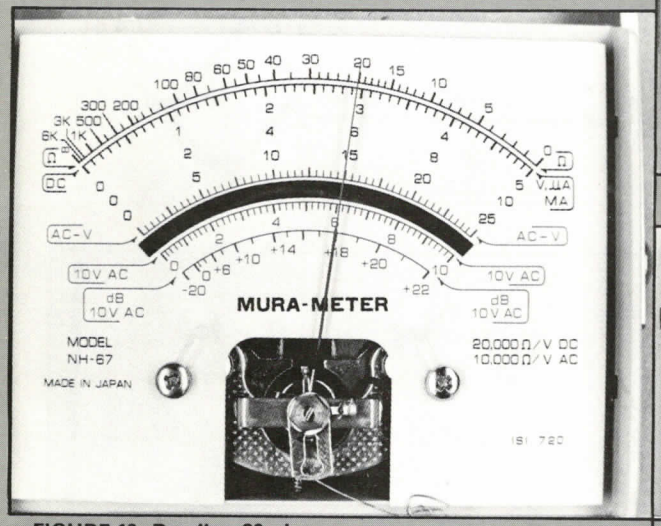


FIGURE 10 Reading 20 ohms.

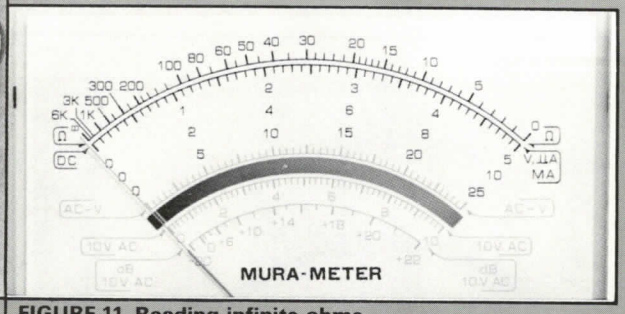


FIGURE 11 Reading infinite ohms.

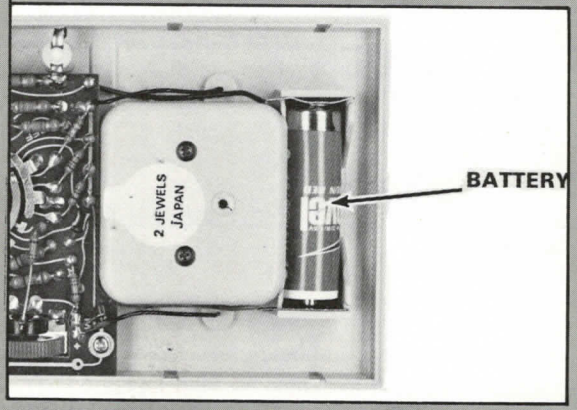


FIGURE 12 The internal battery used by an ohmmeter.

THE OHMMETER

For measurements of resistances, the function selector is set to a position in the ohms range and resistance is read from the ohms scale. Once you've selected a position within the ohms range, you'll have to zero the ohmmeter.

To zero the ohmmeter, connect the test leads together and rotate the ohms adjust control until the meter needle aligns with the zero calibration on the ohms scale. Now you're ready to make a resistance measurement.

Suppose that you have the function selector set to the $\times 1$ position. This means that the reading taken from the meter must be multiplied times 1 to give the actual resistance. For example: If the meter needle points to 20 and the function selector is in the $\times 1$ position, the resistance being measured is 20 $\times$ 1 or 20 ohms.

For the same meter needle position with the function selector set to the $\times 1000$ position, the resistance being measured would be 20 $\times$ 1000 or 20,000 ohms. Because the ohms scale is easier to read accurately between its midway point and zero ohms, try to set the function selector so that the meter needle reads in this portion of the scale.

An additional point about the ohms scale deserves your attention. Notice that the value of the graduations between different sets of numbers vary, for example, each graduation between 9 and 20 is equal to one unit (1, 2, 3, etc.). Yet each graduation between 20 and 30 is equal to two units (20, 22, 24, etc.).

In order to make resistance measurements, your VOM depends upon internal batteries. To determine the condition of the batteries in your VOM, set the function selector to ohms $\times$ 1, connect the test leads together and use the ohms-adjust control to zero the meter. If the needle will not move to the zero position on the ohms scale, the battery must be replaced. You'll find the specific procedure for changing the ohmmeter battery in your VOM's instruction booklet.

When it's used to make a resistance measurement, the polarity of your VOM's leads may be reversed. That is, the internal battery may make the black lead positive and the red lead negative. As a general rule, Japanese-made VOM's reverse lead polarity when set to ohms, while American-made VOM's do not.

Because the ohmmeter depends upon its internal batteries to provide current to the circuit being tested, it is important that no other power be connected to the circuit. If you try to measure resistance in a working circuit, you'll get an incorrect reading and probably damage your meter, too.

In summary, the key to interpreting the ohmmeter portion of the VOM is: Note the scale reading, the value of the function selector, and then multiply the two together to determine the resistance seen by the meter. Select a function-selector position that causes the needle to move to the central or right-hand portion of the scale for ease of interpretation.



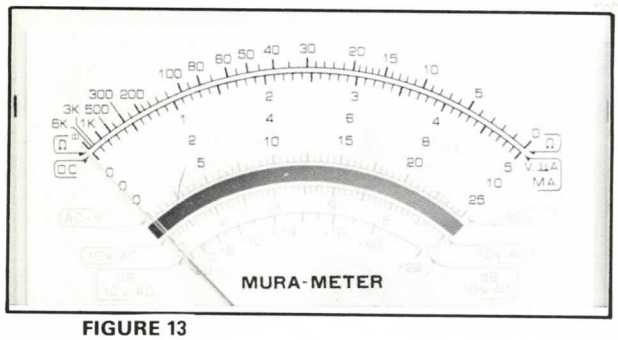


FIGURE 13

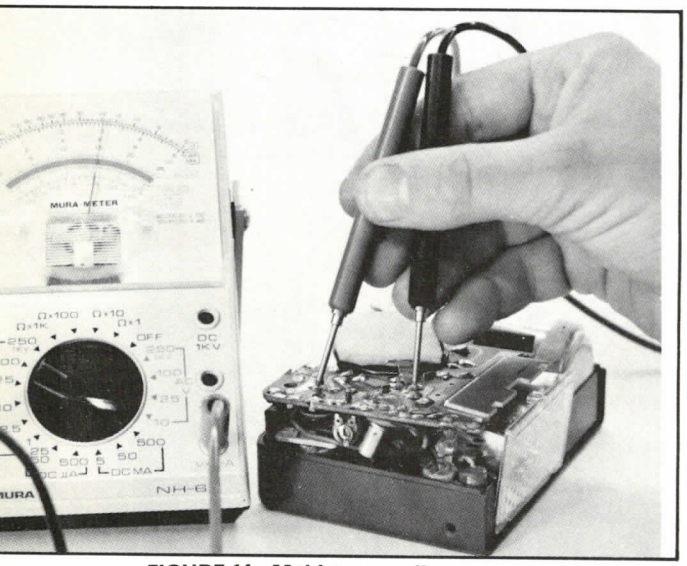


FIGURE 14 Making a reading.

DC VOLTMETER

When the same multimeter is used to measure DC voltages, the function-selector switch is set to a position in the DC-volts range. Just as in the resistance range, there are several positions for the selector switch in the DC-volts range.

The position of the function selector in the DC-volts range is determined by the voltage to be measured. Each function-selector position is for a different maximum reading. For example: On the 10-volts scale, up to 10 volts may be measured without damaging the meter. As a rule of thumb, you'll want to make your first reading of voltage in the highest voltage range so that if something is wrong in the circuit you're testing, you won't damage your meter. For each position of the function selector set in the DC-volts range, there is a scale on the meter face. If you look at this meter face, you will see that the scales go up to 5, 10, and 25, not to .25, 1, 10, 25, 100 and 250. This is because a lot of space on the already crowded meter face would be needed in order to have separate scales for each voltage range. So, the meter user performs a mental calculation to obtain the correct reading from the voltage scale. When the range selector is in the .25, 1, 2.5, 100, or 250 volt position, multiply or divide by ten to determine the voltage being measured. Here the meter needle points to "6" with the function selector set in the 100 V position. To interpret this reading, notice that the highest reading from this scale is 10. $10 \times 10 = 100$ which is the setting of the function selector. Since 10 times the top reading of the scale equals the setting on the function selector, all readings from the 10 scale with the function slector set to 100 must be multiplied times 10. So in this case, the voltage meter is reading 60V. If instead of being on the 100V setting the function selector was set to 1V position, all readings would have to be divided by ten. So for the same needle deflection, $6 \div 10 = .6$ or the reading is .6 volts. You can use a similar technique for almost all multimeters.

When using the voltmeter, it is important that you remember that the voltmeter measures potential difference. For this reason the voltmeter must always be connected in parallel with the circuit or component under test.

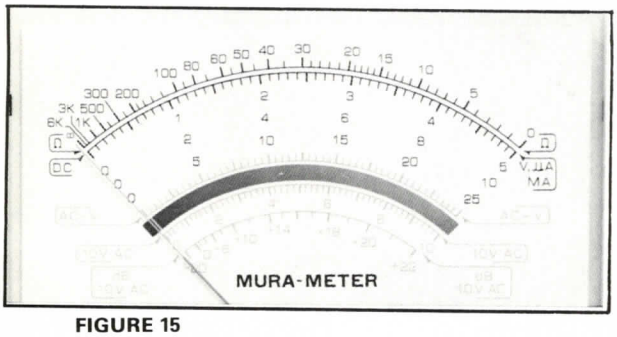


FIGURE 15

DC AMMETER

The same meter scales used to measure DC voltages are used to measure DC current. Because in modern electronic circuits one amp is a lot of current, VOM's are frequently calibrated in milliamps and microamps. Like in the DC-voltage range, you will find several positions for the function selector in the DC-current range. As in the case of the voltmeter, these are maximum readings.

In the case of this meter, the positions are 5, 50, and 500 ma; 50 and 500 ua.

Because of the way the meter scales are marked, you must use the same system as you did for voltage to arrive at the current flowing in a circuit. That is, if the meter needle indicates "20" and the function selector is in the 500 ma position, the current flowing must be 200 ma.

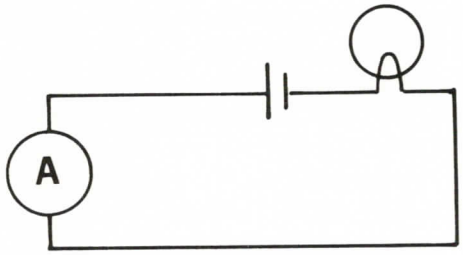


FIGURE 16

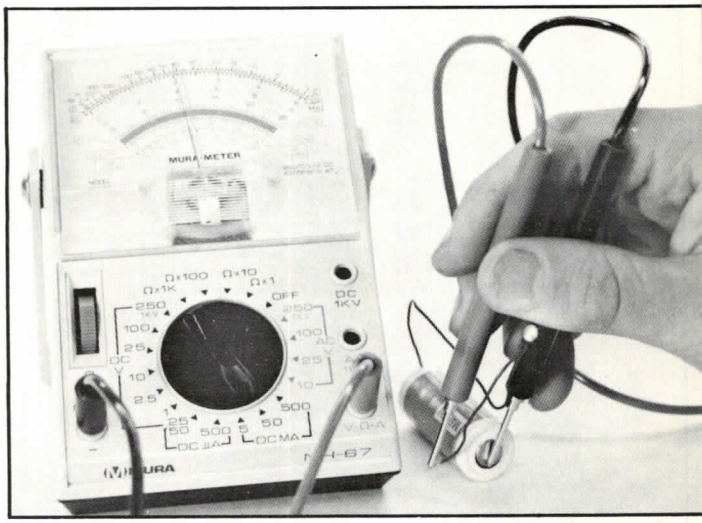


FIGURE 17 Using the milliammeter to measure a lamp's current.

Remember that the ammeter is an electron-flow meter so the ammeter must always be connected in series with the circuit or component under test. Because an ammeter has very low resistance, connecting an ammeter across a circuit or component could easily damage the ammeter or circuit wiring.



FIGURE 18 Schematic symbol for an ohmmeter.



FIGURE 19 Schematic symbol for a voltmeter.



FIGURE 20 Schematic symbol for an ammeter.

AC MEASUREMENT

Before covering the use of the AC scales on the VOM, let's cover some aspects of alternating current in a little more detail.

You've already seen that the voltage in an AC circuit swings first in one direction then in the other. It's this swing in voltage that makes measurements in an AC circuit more difficult. If an ordinary galvanometer were connected to an AC circuit, the galvanometer needle would wiggle back and forth rapidly. So no reading could be made of the needle's position. Because of its wave nature, alternating current must be **rectified,** that is, changed into direct current before a galvanometer is used to make a measurement. We won't go into the details of rectification here—they are covered later in your course.

One more thing complicates making a measurement in an AC circuit and that's RMS voltage, sometimes called effective voltage. The RMS (for root mean square) voltage of an alternating current is 70.7% of the peak voltage. Or, said another way, the RMS voltage × 1.414 equals peak voltage. Almost without exception VOM's read RMS voltage so you'll have to do a little math if you need to know peak voltage.

When you read an AC voltage in the 25, 100 or 250 volt range, use the red scale marked "AC-V" and the black calibration just above it. To read in the 10-volt range, use the scale marked "10V-AC."

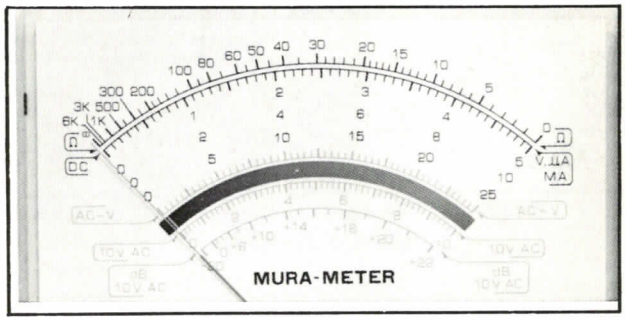


FIGURE 21



FIGURE 22 Using the high voltage scale to measure the voltage of an electronic flash battery.

READING HIGH VOLTAGES

You may find on occasion that you need to measure high voltages. To measure in the thousands of volts using most multimeters, you'll need to follow a little different procedure than you've used for lower voltages. Most meters are similar to the one we'll be using so you can adapt this procedure if necessary.

To measure up to 1000 volts, first determine whether the circuit you'll be measuring is AD or DC. Then set the function selector to 250V, AC or DC as appropriate. Next, plug the red test lead into either the "DC 1Kv" or "AC 1Kv" socket depending upon whether you are making a DC or AC measurement. Your meter is now set up to measure high voltages.

The use of extra caution when testing high-voltage circuits is very important. Connecting and disconnecting the meter leads with power removed from the circuit is a good practice. If you find that you cannot remove power from the circuit, you'll probably want to use an insulated clip on one of the leads. Connect the lead with the clip on it with one hand. Hold your other hand behind your back for this operation. After the first lead is clipped in place, you may test the circuit using the other lead, again being sure to keep one hand behind your back.

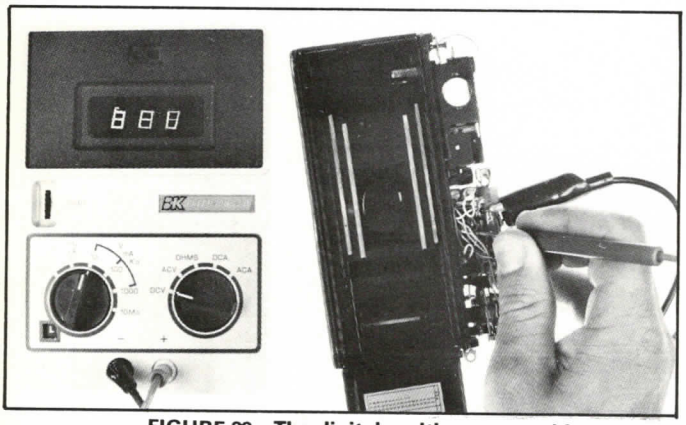


FIGURE 23 The digital multimeter provides a high degree of precision.

OTHER MULTIMETERS

Up until now we've discussed only analog (moving-needle) multimeters. However, there is another type of multimeter rapidly gaining popularity—the **digital** multimeter. Digital multimeters (DMMs) are being seen on more and more service benches because the DMM can give the precise reading necessary for servicing many modern circuits.

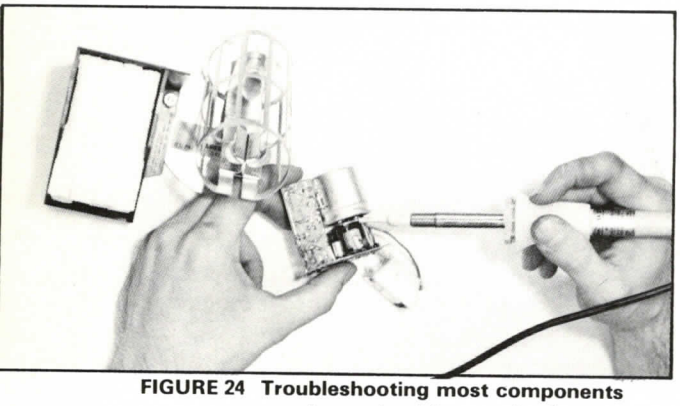


FIGURE 24 Troubleshooting most components requires unhooking one lead.

TROUBLESHOOTING COMPONENTS

If electric circuits never failed, there would be little need for the repair technician to understand their operation. Despite their high degree of reliability the circuits used in photographic equipment do fail, so it's necessary for the photographic equipment technician to be able to locate and correct problems in electrical circuits.

By far the most common trouble spots in photographic equipment are bad batteries, dirty contacts and dirty switches. Weak batteries and dirty battery contacts, if not taken care of first, will make additional troubleshooting difficult if not impossible. Frequently, too, replacing old batteries and cleaning battery contacts restores equipment to proper operation.

Once you are certain that batteries and contacts are not the cause of a circuit's malfunction, it's time to look deeper. Often there are internal switches or contacts in photographic equipment. Locating and cleaning any internal switches is your next step.

If after all internal contacts and switches have been cleaned the trouble remains, proceed to the circuit itself. Because no complete circuits have been studied so far, at this point we'll cover only the identification of defective components themselves.

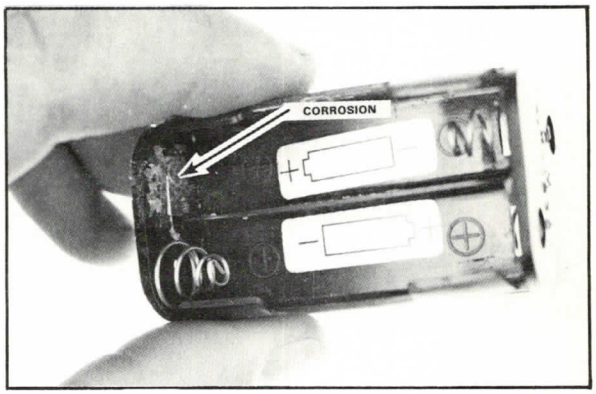


FIGURE 25 Dirty or corroded battery contacts make troubleshooting impossible.

TESTING SWITCHES

This is a simple test using your ohmmeter. Set your ohmmeter on its ohms × 1 scale and connect it to the switch. When the switch is open, your ohmmeter should read infinite ohms; when it is closed, zero to 1 ohm. A switch that always reads zero ohms is damaged. If you can't see what is causing the switch to remain closed and correct the problem, you'll have to replace the switch. If a switch does not read zero to 1 ohm when closed (did you remember to zero your ohmmeter?), it's probably suffering from dirty contacts. If the switch's contacts are exposed, clean them and then retest.

CLEANING SWITCHES

To clean switch contacts, you'll first need to determine if the contacts are plated or not. Most switch contacts found in cameras are plated. Contacts in heavy-duty electrical equipment are not.

A gold-plated contact, the type often found in cameras, will have a slight "glow" to it caused by the plating. The plating is used to protect the switch contact and provide corrosion resistance. To clean a plated contact, use a soft pencil eraser. Use of any stronger abrasive will damage the plating. A few light passes with the eraser should do the trick. After cleaning, be sure to remove all eraser residue.



FIGURE 26 A pencil eraser safely cleans plated contacts.

Unplated contacts, often found in projectors and amplifiers, may be cleaned with a harsher abrasive. For cleaning an unplated contact, a contact burnishing tool works well. To use the burnishing tool, place the tool between the contacts, close the contacts and move the burnisher back and forth several times. When you are done burnishing, be sure to remove any residue.

If you can't clean the switch's contacts easily, you'll probably have to replace the switch.

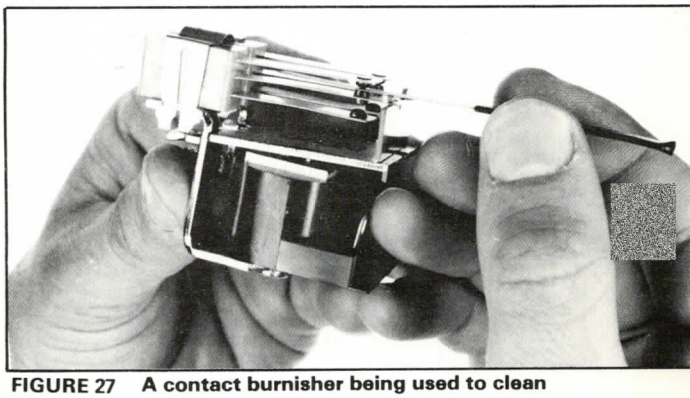


FIGURE 27 A contact burnisher being used to clean unplated contacts.

TESTING FUSES

Most fuses are designed so that a visual check allows you to determine whether the fuse is burned out. However, some fuses do not have an inspection window or are made of opaque material so you'll have to use your VOM to test them. All fuses must be removed from the circuit before they can be tested. A good fuse will read zero ohms, a bad fuse infinite ohms when tested using your VOM.

When you located a bad fuse, it's important you determine what made the fuse blow before installing a new fuse. Replacing the burned out fuse with a new one without correcting the circuit fault which caused the first fuse to blow will just blow the replacement fuse too.

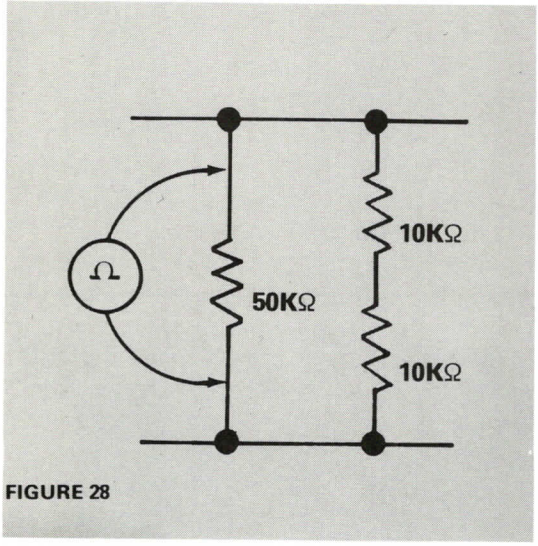


FIGURE 28

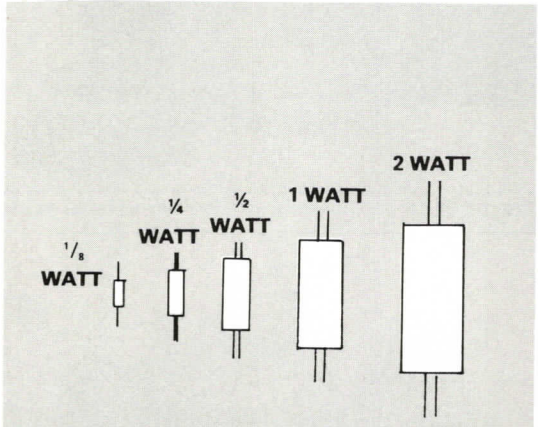


FIGURE 29 Actual sizes of common resistors.

TESTING RESISTORS

Checking a resistor is easy. First determine from the resistor's color code, its resistance and allowable error. Measure its resistance and if your measured resistance falls within the allowable limits, the resistor is good. If not, the resistor is out of tolerance and should be replaced. When you find it necessary to measure the value of a fixed resistor that is in a circuit, first disconnect all power from the circuit to avoid damage to your ohmmeter. Next disconnect one lead of the resistor from the circuit. Here is why: If you measure a 50K resistor in a circuit this way, you will get a reading of about 14K because of the resistance in parallel with the resistor you are measuring. So, always disconnect the resistor you are measuring from the circuit because parallel resistances may cause an erroneous reading. When you replace a resistor, select a replacement resistance equal to that marked on the defective resistor. In addition to matching resistance, be certain that your replacement resistor has the same or greater power rating as the resistor you have removed. Common power ratings for resistors are 1/8, 1/4, 1/2, 1 and 2 watts, so your specifications to an electronics shop might read: "1 resistor 3300 ohms, 1/2 watt."

In most photographic applications, resistors will be 1/8 or 1/4 watt. However, 1/2 watt resistors are less expensive and often more easily obtained that 1/8 or 1/4 watt resistors. So, if space allows, a 1/2 watt resistor could be substituted for 1/8 or 1/4 watt resistors. If it is necessary to bend the leads of a replacement resistor, it's important not to crack the case of the resistor while bending the lead. A good way to prevent a resistor case from being cracked is to hold the lead in a pair of pliers then bend the lead next to the pliers rather than next to the resistor body. This bending procedure works well for most electrical and electronic components and is especially important for some semiconductors.

TESTING A CAPACITOR

Besides being useful in locating bad resistors, your ohmmeter can give you a clue to the condition of a capacitor. A suspicious reading using your ohmmeter lets you know that a more exact test of the capacitor is needed. The first steps in testing a capacitor are the same as the first steps in testing a resistor. Disconnect the power and remove a least one lead from the circuit. Next, since a capacitor is a device designed to store an electrical charge, discharge the capacitor. Failure to discharge a capacitor could result in a severe electrical shock for you or in permanent damage to your meter. STOP! Don't reach for that screwdriver. First look at the capacitor. Some capacitors store enough charge to damage a screwdriver. If the capacitor is marked to operate at more than 25 volts or indicates a capacitance of over 10μfd, use a discharging resistor. A 100 ohm, 10 watt resistor is excellent for use in discharging capacitors. By wiring up your discharging resistor as we have with clip-on leads and a switch, you'll avoid the possibility of an electrical shock. After connecting your discharging resistor to the capacitor terminals for a few seconds, use your voltmeter to test for any charge remaining on the capacitor. Make your first voltage test on a scale which will safely read the voltage marked on the capacitor, then work down. If on a low scale the capacitor to be tested reads zero volts, you are ready to disconnect one lead of the capacitor from the circuit.

Test capacitors using the ohms $\times 100$ or $\times 1000$ scale. Capacitors marked in microfarads to about .1 μfd should read infinite ohms with possibly a momentary deflection of your ohmmeter's needle. Capacitors between .1 μfd and 10 μfd should be between several hundred million ohms and infinite ohms. Again your ohmmeter's needle may bounce slightly as the capacitor is connected to the meter. Capacitors above 10 μfd will probably not read infinite resistance and the ohmmeter needle will make a pronounced swing toward zero as the meter leads are connected. But, after swinging toward zero, the meter needle should move toward infinite ohms. If a capacitor reads zero ohms initially and remains at zero ohms, it'll have to be replaced.

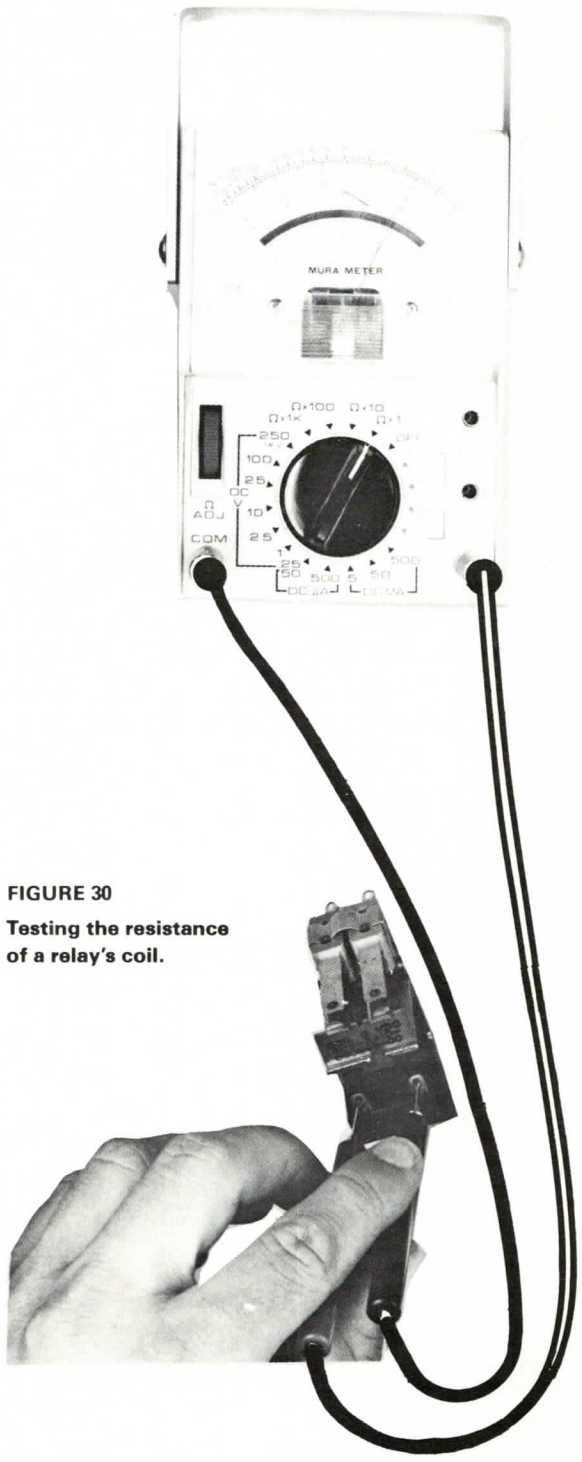


FIGURE 30
Testing the resistance of a relay's coil.

TESTING A COIL

Although a coil is often used in circuits for its electromagnetic properties, to an ohmmeter a coil looks like a resistor. To test a coil, connect your ohmmeter to the coil's leads. Infinite or zero resistance may indicate a bad coil. Often you will have to consult a schematic diagram or parts list to be sure.

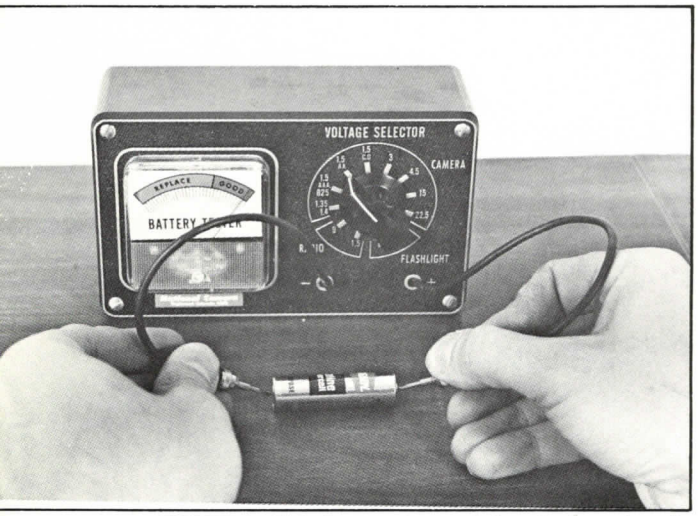


FIGURE 31 This battery is good, but for how long?

LAMPS

Although the best test for a filament-type indicator lamp is to operate the lamp from a power supply known to be functioning correctly, an ohmmeter will allow you to determine if a filament lamp is bad. Filament lamps should have a fairly low resistance. A filament lamp reading infinite ohms is bad and must be replaced.

Due to their high turn-on voltages, an ohmmeter cannot be used to test gas-filled lamps. However, there is a test you can make. With the circuit to which the suspect gas-filled lamp is connected operating, measure the voltage across the lamp's leads. Most gas filled lamps require about 90 volts to turn on, so if you measure about 90 volts you'll probably want to try substituting another lamp for the one in the circuit.

TEST YOURSELF QUIZ #11

1. When troubleshooting a battery operated circuit, the first step must always be DISCONNECT - BATTERY - TEST IT.

2. If you find it necessary to clean plated contacts, a ERASER makes an excellent cleaner.

3. If you must replace a 3300 ohm 1/4 watt resistor, a 3300 ohm 1/2 watt or a 3300 ohm 1/8 watt (circle one) resistor may be used

4. Before testing a capacitor you must always DISCHARGE the capacitor.

5. An ohmmeter reading of a gas filled lamp is "∞ohms." Why wouldn't you replace the lamp? VOLTAGE IS TOO HIGH

TESTING BATTERIES

You might suspect from the description of how a battery works that a battery will keep on going until it uses up its electrodes or its electrolyte. Although sometimes a battery's electrolyte will eat up an electrode, this seldom happens. In most cases, a battery must be replaced because it develops a high internal resistance. As the battery uses it electrodes and electrolyte to convert chemical energy into electrical energy, by-products are produced. It's the by-products of converting chemical energy into electrical energy that causes an increase in a battery's internal resistance. Increased internal resistance in turn hampers the flow of electrons.

Because of advances in battery technology, modern batteries will remain good for long periods of time. This is particularly true of the batteries used in exposure meters. It's not uncommon for an exposure meter battery to last a year or more. Unfortunately, the same battery when it fails may go from a usable to an unusable condition in only hours. Since no battery tester can predict the life remaining in a battery, it's safest to replace batteries before beginning a repair.

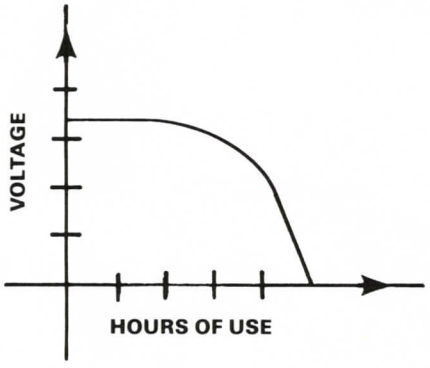


FIGURE 32 Output of an exposure meter battery.

RECHARGABLE BATTERIES

Much of today's portable photographic equipment depends upon built-in nickel-cadmium batteries for its operation. This is an advantage for the user of the equipment because it's not necessary to install new batteries frequently. The built-in batteries are simply recharged and the equipment is ready to go again. But rechargeable batteries don't last forever. Even if the batteries are carefully maintained they'll only pass through a limited number of charge/discharge cycles before they will no longer hold a charge. A nickel-cadmium battery that will no longer hold a charge must be replaced. Although it's not always possible to rapidly identify a bad nickel-cadmium battery, there are two definite indicators of an unusable battery: A voltage reading of zero or a reverse polarity.

Even when discharged, a nickel-cadmium battery should have an open circuit voltage (no load connected) of greater than zero. A zero voltage reading under no load means that replacement is in order. A nickel-cadmium battery with a voltage the reverse of what is indicated on its terminals is also bad and will have to be replaced.

Sometimes a good nickel-cadmium battery will refuse to operate equipment. This battery may have acquired a "memory." Nickel-cadmium batteries develop a memory if they are seldom discharged fully. To remove the battery's memory, leave the equipment the battery is in running for several hours. Then recharge the battery.

In the final analysis: A bad nickel-cadmium battery may be hard to spot. You may have to install a replacement battery in order to be certain that the original batteries are not up to snuff.



FIGURE 33 Replacement rechargeable batteries.

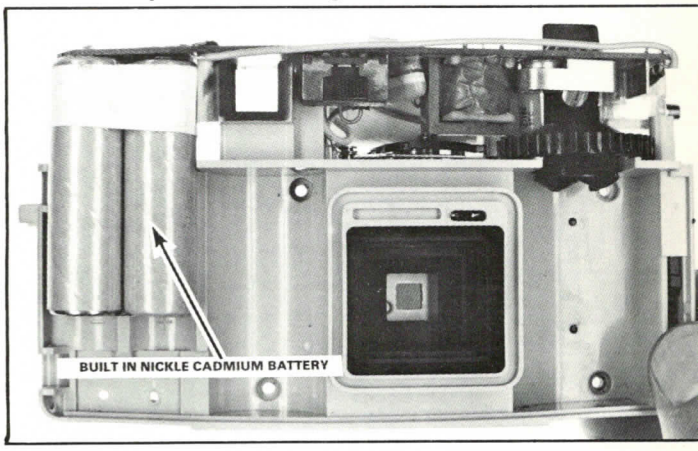


FIGURE 34

USING COMPLEX SWITCHES

In the circuits we've studied so far, only one type of switch has been used—the single-pole, single-throw type. Often in more complex circuits than we've been looking at, a more complex switch is needed. Perhaps a switch which will alternately connect one of two different loads to a power source.

Possibly a switch is needed which will control two separate circuits simultaneously. The dashed lines indicate that both switches operate together. The switches open together and close together, yet remain electrically separate. Writing out single-pole, single-throw: double-pole, double-throw; double-pole, single-throw would not be practical on a circuit diagram or parts list, so abbreviations are used.

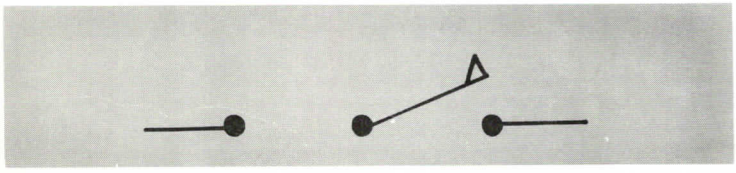


FIGURE 36 SPDT switch.

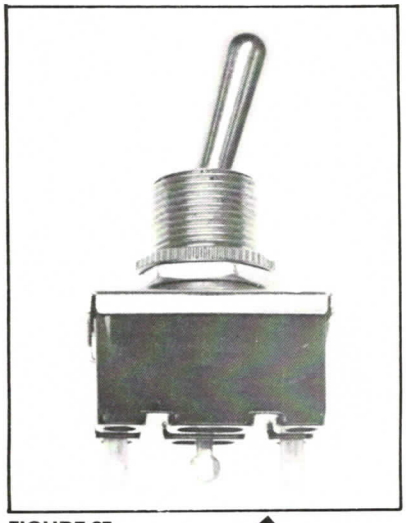


FIGURE 35
This is a single pole, double throw switch.

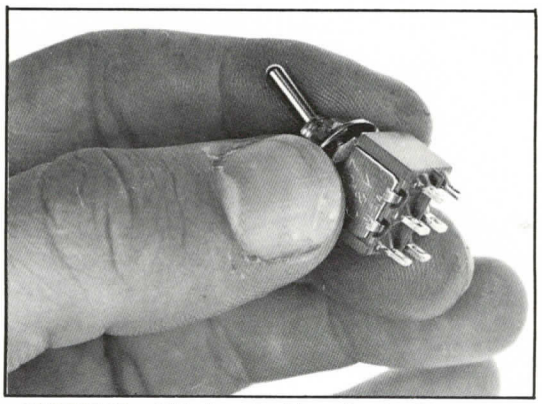


FIGURE 37 **This is a double pole, double throw switch.**

Single-pole, single-throw—SPST
Single-pole, double-throw—SPDT
Double-pole, single-throw—DPST

If a switch has more than two poles or more than two positions, numbers are used to indicate the poles and positions. For example:

SP 3T
DP 3T
3P 4T

Notice in all these examples a dashed line is used to show that although the poles are electrically independent, they are mechanically linked.

In each of the examples we've seen so far, the movable contact in each section of the switch is in a similar positon. This is not always the case. This is a complete diagram of a switch in which the movable contact is not in the same position in each of the ganged switches. Notice that each switch contact is numbered for easy identification and that each section of the three-part switch is identified as being a part of switch 1. Switch 1_a with 8 contacts, $SW1_b$ with 8 contacts and $SW1_c$ with 8 contacts. You'll see even more complex switches occasionally. Fortunately, photographic equipment seldom uses complex switches.

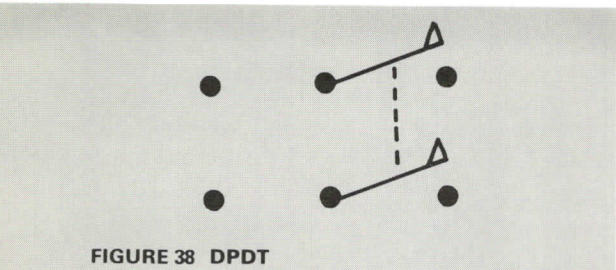


FIGURE 38 **DPDT**

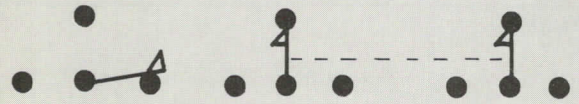


FIGURE 39 **SP3T**

FIGURE 40 **DP3T**

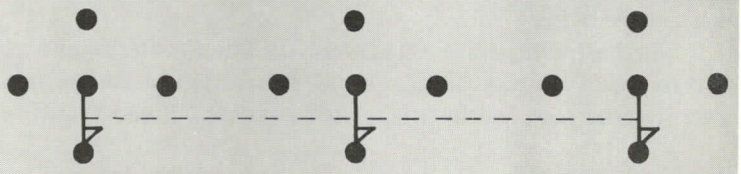


FIGURE 41 **3P4T**

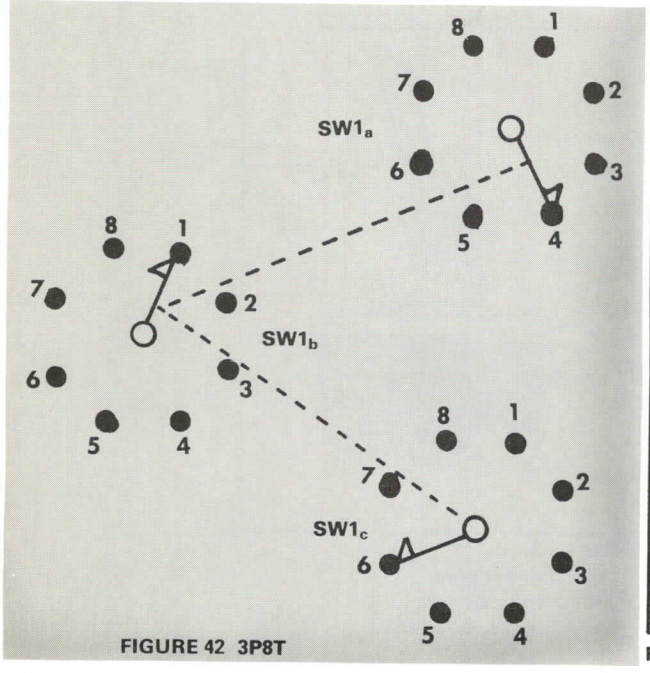


FIGURE 42 **3P8T**

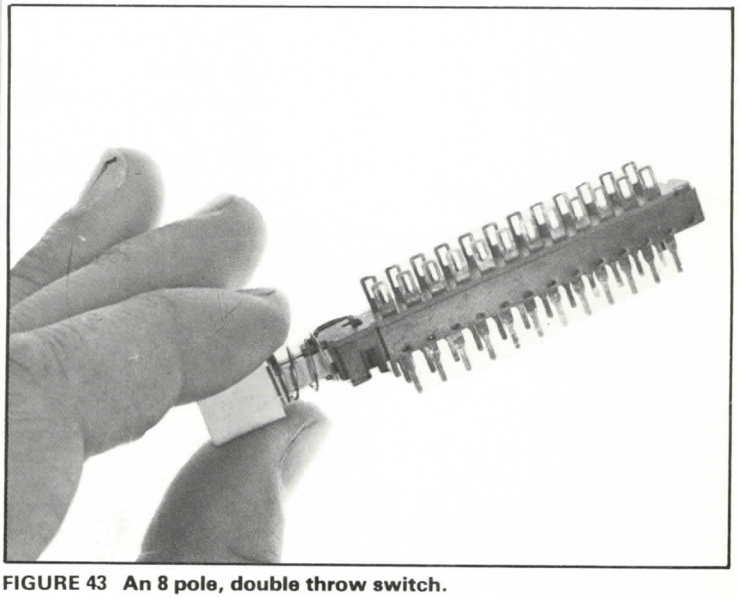


FIGURE 43 **An 8 pole, double throw switch.**

SOLDERING

Electrical connections may be made in a number of ways. Wires may be twisted together, looped or hooked. Conductors could also be taped together or placed touching each other. A circuit could be constructed using any of these methods. However, the circuit would not be very reliable. A reliable electric circuit requires both a good mechanical and a good electrical connection to be made

You've probably seen soldered connections in a great many electrical devices because soldering meets both requirements for a good connection. Soldering provides a good electrical connection and gives mechanical strength. As an added bonus, soldered connections are inexpensive.

What do you need to solder connections? You'll need solder, of course, a soldering iron, and practice. A holder for your soldering iron and a sponge-type tip cleaner will make soldering easier.

Strictly speaking, a soldering iron is a large, high-wattage tool, while a soldering pencil is the instrument most often used in electric circuit repairs. Since most technicians call their soldering pencil a soldering iron, we'll be doing this too.

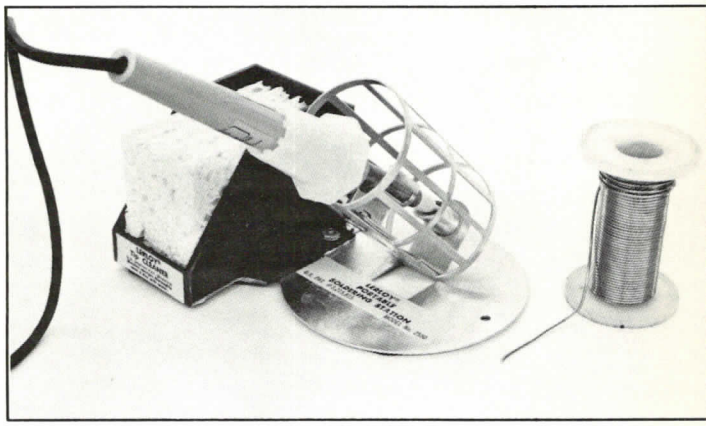


FIGURE 44 A soldering station.



FIGURE 45
A 35 watt soldering iron.

SELECTING A SOLDERING IRON

Soldering irons or their packaging will carry information about the soldering iron. You'll need to read this information in order to select the proper iron. After making sure that the soldering iron you're considering operates on household circuits, determine the wattage of the soldering iron. The wattage rating of the soldering iron tells you how much electrical energy is being converted to heat by the iron. Because an iron that provides too much or too little heat will make soldering difficult, you'll need to select the correct wattage for the job. To the electrical technician, the most useful iron is in the 25 to 35 watt range. Selecting an iron of a much higher or lower wattage could result in damage to the circuits you're working on.

CHOOSING SOLDER

A visit to an electronics wholesaler will reveal a wide variety of different solders available for use by the repair technician. Which solder is best? It depends a lot on the job to be done as well as on the technician's preferences. The best solder to start with is a 60/40 alloy, radio-grade solder containing flux.

The flux in the solder is designed to prepare a properly cleaned conductor to accept solder. The flux removes very thin oxide layers from the material being soldered. It also helps break the surface tension of the molten solder.

Some solders contain acid flux. Acid-flux solders, often called acid-core solders, are for heavy-duty work, repairing radiators, fixing downspouts and plumbing. An acid flux will destroy your circuit, so make sure that the solder you select is a rosin flux or rosin-core solder.

Another consideration is the guage of the solder. Electrical solders are commonly available in guages of 18, 20, 22 and 24. You'll probably find that 20 or 22 guage solder is the easiest to work with. Too heavy a guage solder could result in too much solder being applied to your connection. Too small a guage solder will require long lengths of solder to be used for each connection.



FIGURE 46
Plated tip.

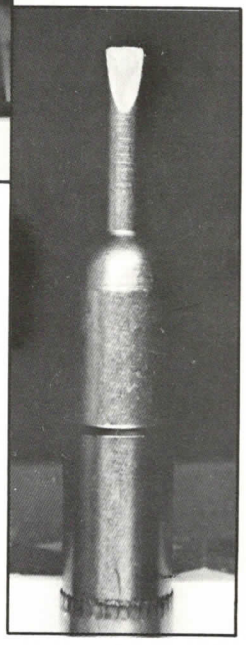


FIGURE 47
Unplated tip.

TINNING YOUR SOLDERING IRON

A fast, clean soldered connection requires a bit of preparation. Before you are ready to solder, you'll have to tin the tip of your soldering iron. Tinning the tip of your soldering iron does two things: It improves the tip's heat transfer and it prolongs the life of the tip. Examine the tip supplied with your iron. If it's a copper color, it's an unplated tip. A silver colored tip is plated. We'll talk more about plated tips later.

First, the steps you'll need to take to tin an unplated tip. In addition to your soldering iron and solder, you'll need a file to prepare the tip. Plug in your soldering iron and allow it to begin warming up. Wait about a minute and touch the end of a piece of solder to the tip. If the solder doesn't melt, let the iron warm up for

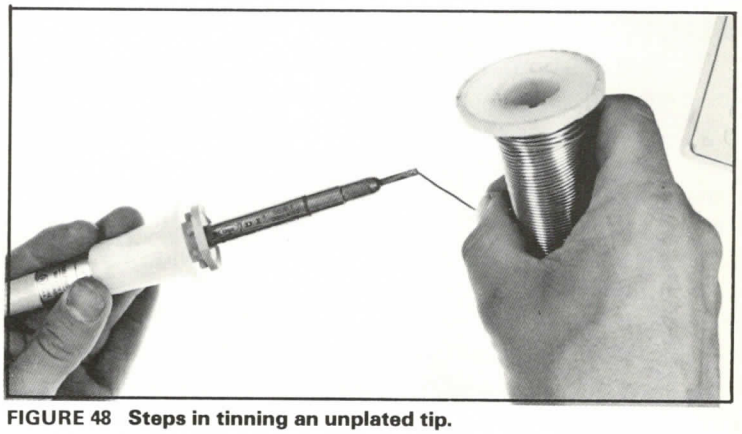


FIGURE 48 Steps in tinning an unplated tip.

another 30 seconds and try again. As soon as the tip is hot, melt a small blob of solder on it. Now, use your file to work the molten solder around the business end of the tip. Keep adding solder and filing away dark deposits until the tip is smooth. Solder applied to a properly tinned tip should flow on smoothly and not ball up. Even if it's kept tinned, an unplated tip will gradually deteriorate. Deterioration is due to the tin in solder eroding away the unprotected copper tip. As the unplated tip is eroded away, it will lose its shape so you'll have to use your file to reshape it.

Your soldering iron may be equipped with a plated tip mentioned earlier. If so, it's not essential to tin the tip. When tinning the plated tip, do not use a file. A file will damage the tip by removing its plating. A properly tinned, plated tip should last for years. Tinning also provides a better transfer of heat.

To keep the tip of your soldering iron clean, a small, wet-sponge type soldering iron cleaner is helpful. By plunging the tip of your soldering iron through the sponge periodically while you're working, you'll restore the tip to its shiny working condition.

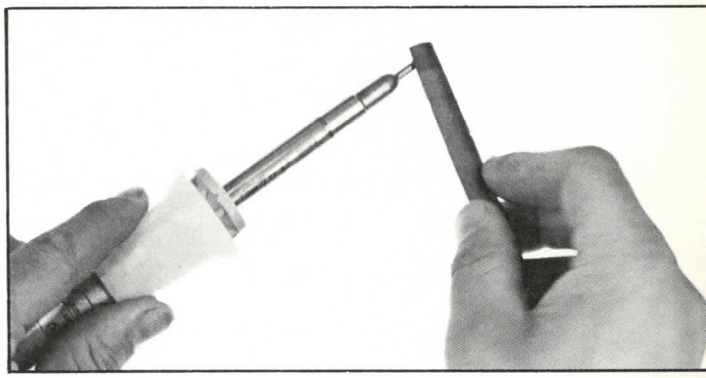


FIGURE 49

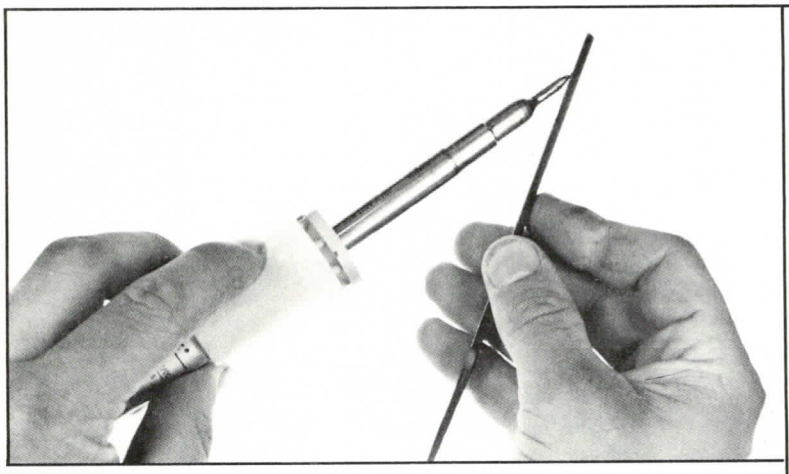


FIGURE 50

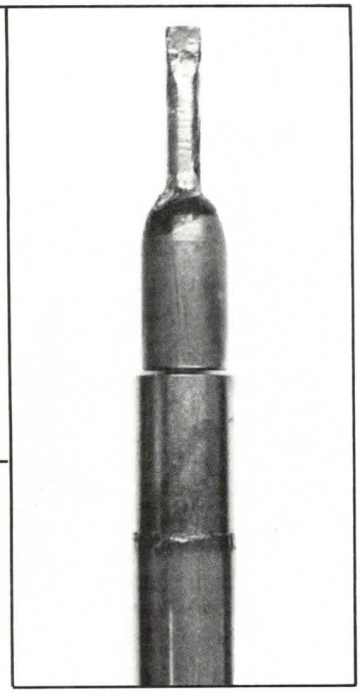


FIGURE 51
Tinned tip ready for use.

TEST YOURSELF QUIZ #12

1. A relaible electric circuit requires a good MECHANICAL connection as well as a good ELECTRICIAL connection.
2. The solder you select for electrical work must not contain ACID flux because it will destroy your circuit.
3. A soldering iron's wattage rating tells you how much electrical energy is converted to HEAT by the iron.
4. Before using an unplated soldering iron tip you must TIN the tip.
5. A clean tip will be SHINY (shiny, dull black) (choose one).

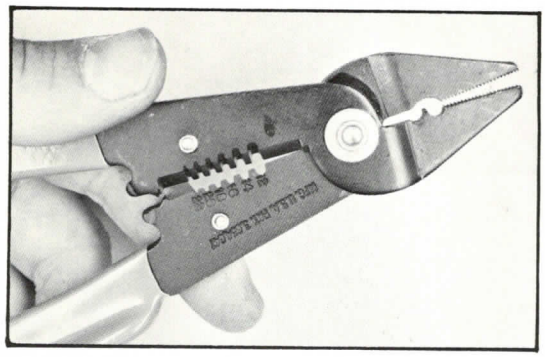


FIGURE 52
A combination wire stripper, pliers and electrical terminal tool.

PREPARING A WIRE

Before you can solder, you'll have to prepare the work to be soldered. Insulated wire will have to have its insulation removed. Many conductors will have to be cleaned as well. For removing insulation from wire, particularly the small wire used in cameras, a wire stripper is very handy. Otherwise a razor blade or sharp knife may be used. Be sure to hold the blade or knife at an angle so that your cut is angled.

The reason for the angle cut is to prevent your nicking the wire. A nick in a solid wire can result in the wire breaking at the nick when you bend the wire. If you cut straight into a stranded wire, you'll probably cut a few of the strands. This mechanically and electrically weakens the wire. In the case of some very fine wire used in cameras, cutting straight into the wire will cut straight through the insulation and conductor before you have a chance to realize what you have done.

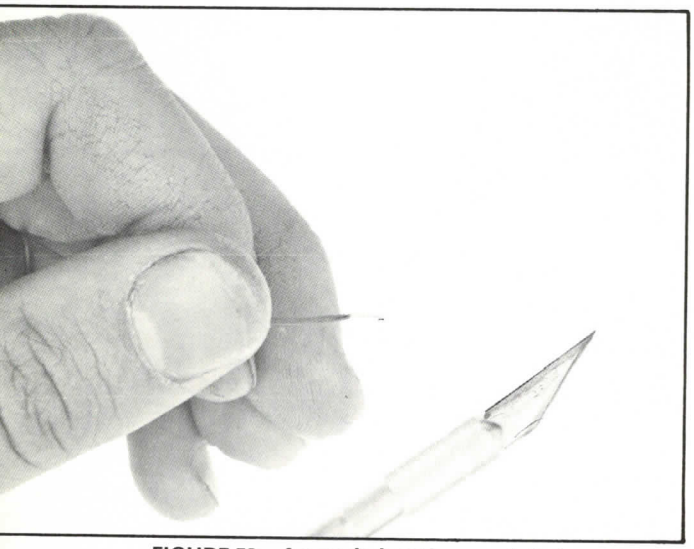


FIGURE 53 An angled cut is especially important with fine wire.

TINNING A WIRE

Some wire, especially pretinned wire, may be soldered as soon as the insulation has been removed. Other wire must be cleaned and tinned first. An excellent cleaner for fine wire is a ball-point pen eraser. A small piece of sandpaper will work too. Either of these cleaners will work well on a PC (printed circuit) board too. Just remember to remove the residue following cleaning.

Tinning a wire or other conductor is done by applying a light coating of solder to the wire. The proper technique for tinning or for making a soldered connection is to first apply the soldering iron then the solder to the work. Sometimes you'll find it faster to touch the iron to the work and then apply solder where the iron and work meet. Never apply solder to the iron and then try to transfer the molten solder to the work. A solid wire may be tinned almost to the insulation. However, you need to tin only the portion of the wire to be soldered later. When you tin a stranded wire, a different technique is needed. After stripping its insulation, twist the stranded conductor so that no loose strands of wire are sticking out. In order to prevent a stranded wire from being unraveled during handling, tin the end of the wire. Don't tin all the exposed conductor as this will result in the wire becoming stiff and difficult to bend.

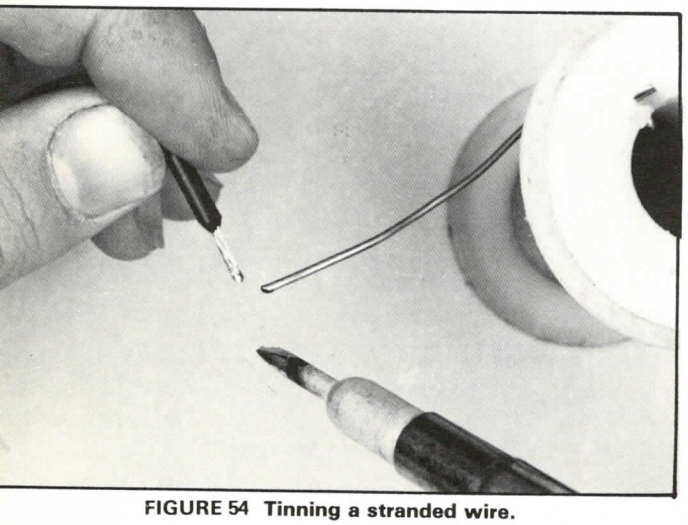


FIGURE 54 Tinning a stranded wire.

PRINTED CIRCUITS AND FLEX CIRCUITS

Most of the wiring you'll be seeing will be on PC boards or flex strips. So, we'll cover soldering to these circuits first.

Printed circuitboards vary quite a bit in manufacture and layout. While most modern PC boards are not very sensitive to heat, it's easy to damage older boards. Too much heat applied to a land (the conductor) on a PC board will result in the land peeling away from the board. A peeled land can't be reglued. You'll have to use a piece of wire to replace it. The key to working on a PC board without doing any damage is to work quickly. And the key to working quickly is to have clean conductors and a properly tinned iron.

Don't tin a PC board before soldering to it—you'll plug up its holes. It's important to use enough solder to make a connection. Too much solder can short or bridge lands that are not supposed to be connected. Too little solder could make a poor mechanical connection.

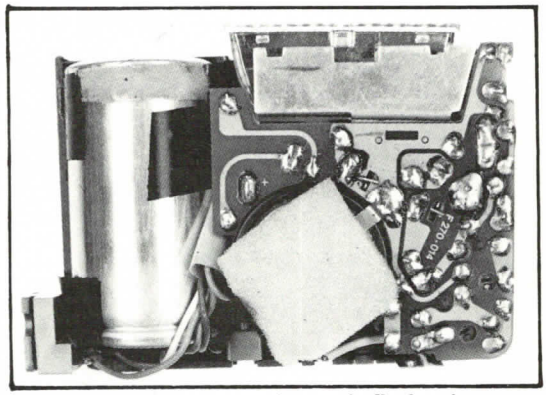


FIGURE 55 A compact electronic flash using a printed circuit.

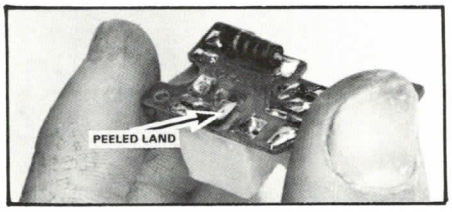


FIGURE 56

DESOLDERING

You'll have to remove components from PC boards occasionally. Removing a component from a PC board is made easier if you have on hand a desoldering wick, solder vacuum pump or a similar product.

For the repair of photo equipment, many technicians use a desoldering wick. This is because the desoldering wick is easily manipulated in the often crowded circuits used in photo equipment.

To desolder using a wick, hold the wick and your soldering iron against the work being unsoldered. When the solder melts, it will be absorbed by the wick allowing you to remove the lead from the PC board. Before the next use of the wick, you'll have to clip off the portion of the wick filled with solder.

A vacuum tool is used differently. The tip of the tool is placed against the connection just as the solder melts, and the tool's trigger pressed. A powerful suction draws the molten solder away from the connection. Don't ever use compressed air to blow solder away from a connection. There's no telling where all the tiny bits of solder will end up.

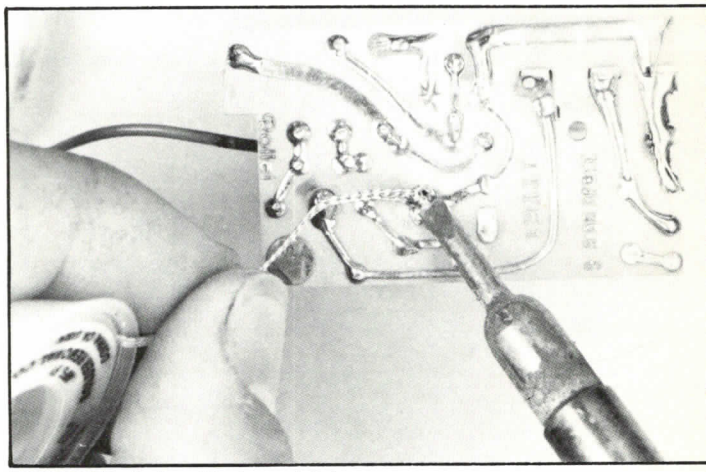


FIGURE 57 A desoldering wick in use.

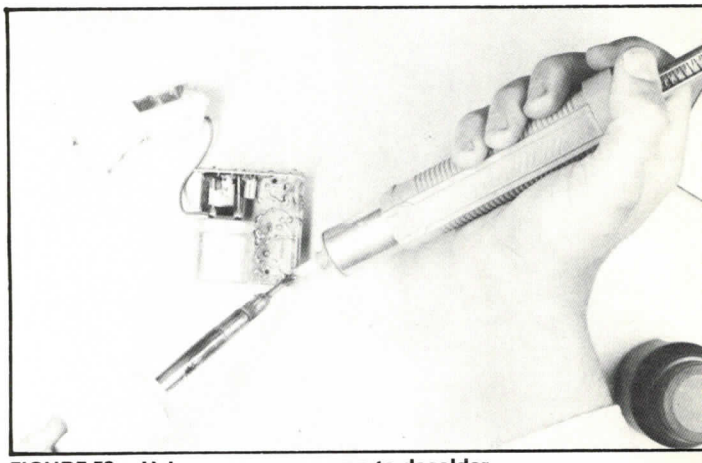


FIGURE 58 Using a vacuum pump to desolder.

The technique for working on flex circuits is nearly the same. The major difference is that flex circuits are more delicate. Not only do flex circuits melt from excess heat, they also break and tear easily due to careless handling. You'll probably want to practice working on PC boards for a while before tackling a flex circuit.

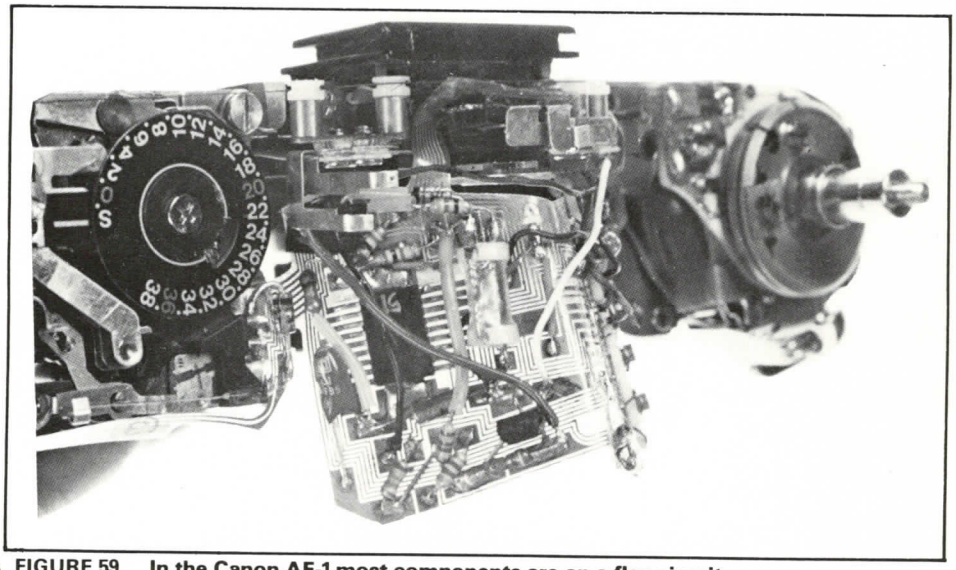
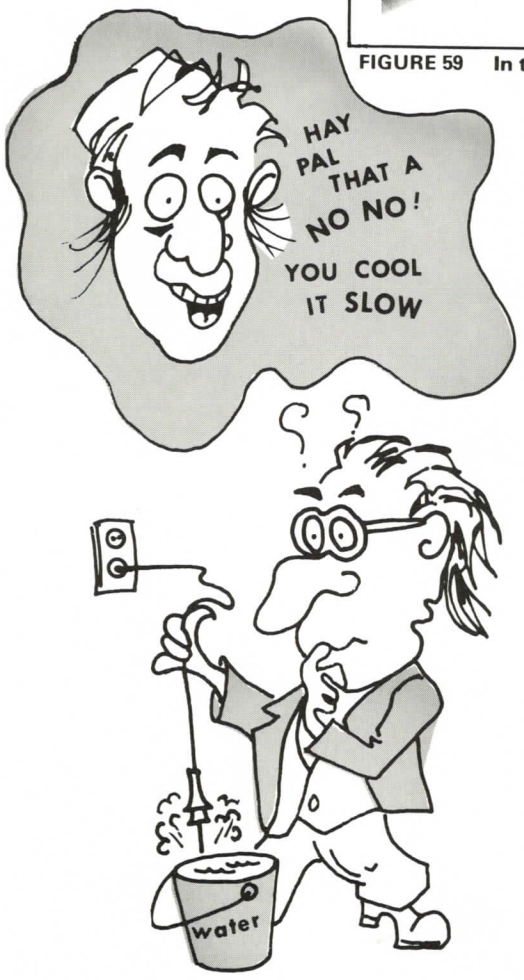


FIGURE 59 **In the Canon AE-1 most components are on a flex circuit.**



CONNECTING WIRES

A number of splices used by electronic technicians provide good electrical contact and high mechanical strength. To make these splices, the wires are first tinned, then wrapped together. The application of heat from a soldering iron and a little solder completes the splice.

Often the wires in a camera are too small to be twisted together. But since there is not any appreciable amount of strain on the wires, they may be safely left untwisted. A slight twist, or in the case of very tiny wires, just placing the wires side by side and soldering will do. After making your splice, you'll need to protect it. Electrical tape may be used or you may prefer to use shrink tubing. If you decide on shrink tubing, you'll have to slip a small piece of tubing over one end of the wire to be connected before you solder.

Be sure that the tubing is long enough to cover the completed splice. After soldering the connection, slip the tubing over it and hold your soldering iron beneath the tubing to cause the tubing to shrink tight around the splice.

You'll find shrink tubing to be quite a space saver compared to electrical tape when you're working in a camera.

When you're done soldering, before you unplug your soldering iron, tin the tip and then cool the iron for storage. By tinning the tip just before cooling, you'll prolong its life.

TEST YOURSELF QUIZ #13

1. Before tinning a stranded wire TWIST the strands together.

2. Stranded wire is usually tinned only on its end because if it is tinned all the way back to the insulation it becomes STIFF.

3. PC in PC board means: PRINTED CIRCUIT.

4. On a PC board, the lands are the CONDUCTORS.

5. Before you unplug your soldering iron to put it away, you should TIN the tip.

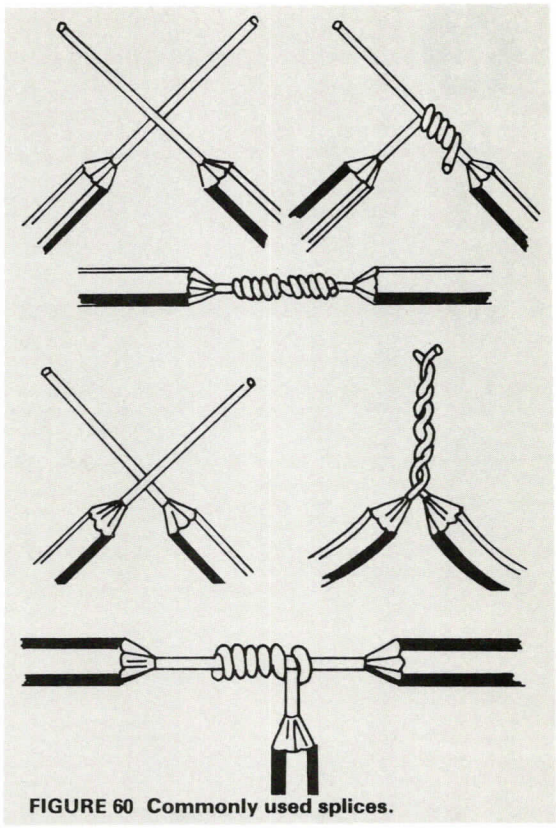


FIGURE 60 Commonly used splices.

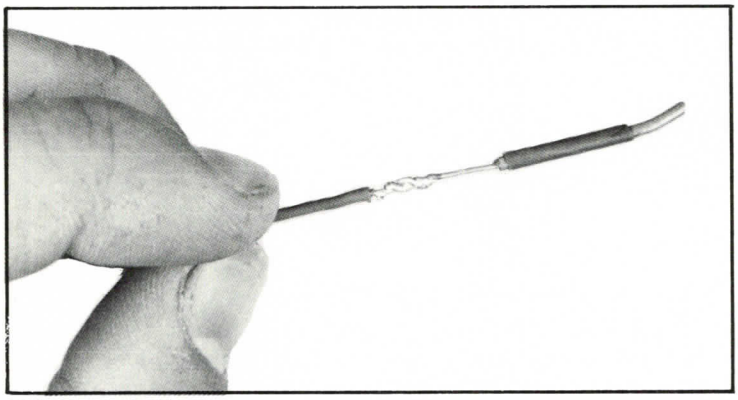


FIGURE 61 Solder.

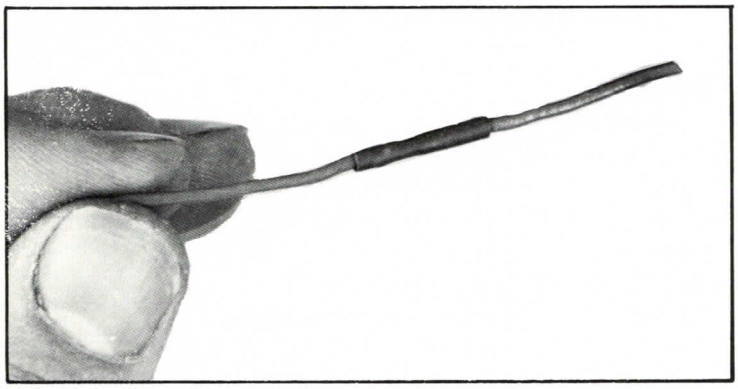


FIGURE 62 Slip tubing over the connection.

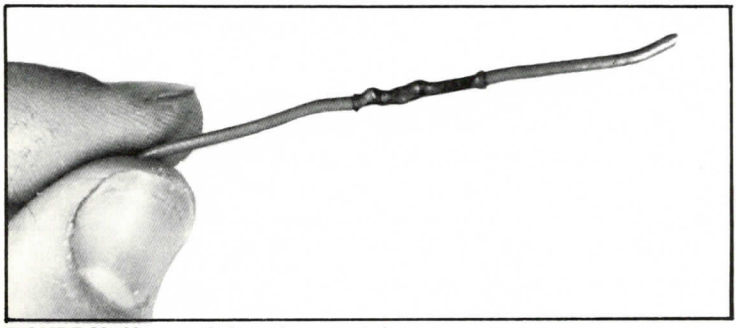
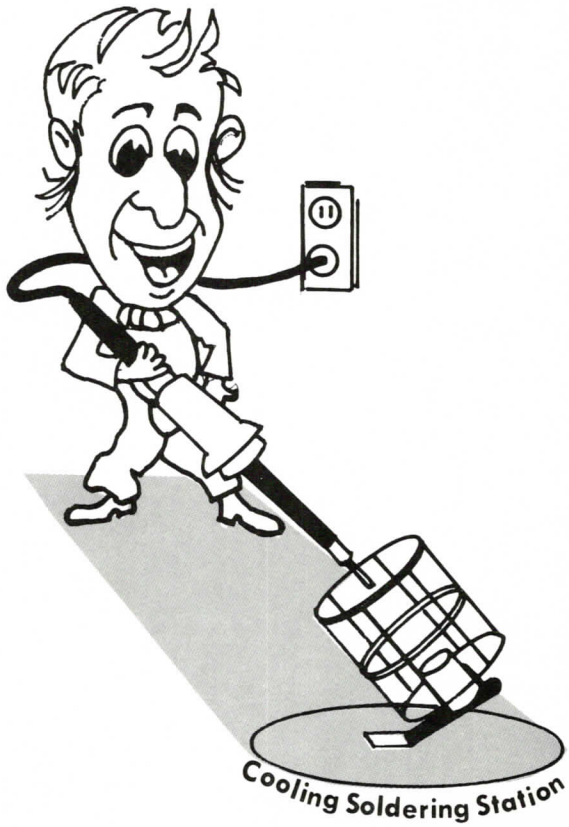


FIGURE 63 Heat and the tubing shrinks.





ANSWERS

ANSWERS TO TEST-YOURSELF QUIZZES

QUIZ #1

1. The fundamental building block of all matter is the **atom.**
2. The **nucleus** of the atom is surrounded by orbiting **electrons.**
3. Atoms with **free electons** in their outer shells make good conductors.
4. Atoms with few free electrons are **insulators.**

QUIZ #2

1. Having more electrons at one end of a conductor than at the other creates a **potential difference.**
2. PD and EMF are both measured in **volts.**
3. Electron flow is measured in **amps.**
4. A circuit doing work **resists** the flow of electrons.
5. Chemical energy is converted to **electrical** energy in a battery.

QUIZ #3

1.



2. When working with Ohm's law, E is use to indicate volts, I indicates current and R indicates resistance.
3. V stands for **volts,** A for **amps** and Ω for **resistance.**
4. The problem is I = E/R. The solution will be in **amps.**
5. Using Ohm's law, R = E/I, we have 1½ volts/1 amp = **1½ ohms.**
6. Ohm's law gives E = IR, so ½ amp × 10 Ω = **5 volts.**
7. I = E/R, so 18 volts/36 Ω = **½ amp.**

QUIZ #4

1. The **resistance** in a circuit converts electric energy into other forms of energy.
2. Watts = E × I or **volts × amps.**
3. A milliamp is 1/1000 amp, so there are **2000 milliamps** in 2 amps.
4. Kilo means **multiply** by 1000.
5. 22MΩ is 22 Megohm or **22 million ohms.**

QUIZ #5

1. Battery
2. Open Switch
3. Ground (chassis)
4. Closed switch
5. Resistor
6. Connected wires

Ohm's Law Problems

7. Using Ohm's law I = E/R, so I = 1.5V/1.5 Ω = **1 amp.**
8. Using Ohm's law R = E/I, so R = 10V/½ A, R = 10V × 2/1, **R = 20 Ω .**
9. Using Ohm's law, E = I × R, so E = ¼ A × 100 Ω , E = 100/4, **E = 25 V.**
10. I = E/R, I = 1 volt/4 Ω , **I = ¼ A.**
11. **Zero amps.** The switch is open.

QUIZ #6

1. There is only one electron path in a **series** circuit.
2. Kirchoff's voltage law says that sum of the **voltage drops** in a series circuit equals the **voltage** applied.
3. The battery provides **8 volts.**
4. Kirchoff's current law says that the current into a circuit must equal the current out. So, **2 amps.**
5. A battery will see the **sum** of the resistances in a series circuit.
6. Each of the branch currents must come from the battery, so total current is 1a + 3a + ¼ a = **4½ amps.**

QUIZ #7

1. A mercury cell is a **1.35 V.** cell. Three mercury cells in series will provide **4.05 V.**
2. Three mercury cells in parallel provide **1.35 V.**
3. SW_1 is open, SW_2 is closed.
4. **6 cells** will provide 9v.
5. $R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$, $R_{eq} = \frac{18 \times 18}{18 + 18}$, $R_{eq} = \frac{324}{36}$, $R_{eq} = 9\Omega$ or $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$, $\frac{1}{R_{eq}} = \frac{1}{18} + \frac{1}{18}$, $\frac{1}{R_{eq}} = \frac{2}{18}$, $\frac{1}{R_{eq}} = \frac{1}{9}$, $R_{eq} = 9\Omega$.
6. Total current is ½ amp, so since the voltage is 9 volts, total resistance $= \frac{9 \text{ volts}}{\frac{1}{2} \text{ amps}}$ or 18Ω. The known resistor is 9Ω, so the value of R_{eq} is 9 Ω because in a series circuit the resistances are added to obtain total resistance.
7. I = E/R, so I = 4 volts/12Ω = ¼ AMP with SW_1 open. With SW_1 closed, the equivalent resistance R_{eq} is $1/R_{eq} = 1/12\Omega + 1/24\Omega$, $1/R_{eq} = 2/24 + 1/24$, $1/R_{eq} = 3/24$, $1/R_{eq} = 1/8$, $R_{eq} = 8\Omega$.
8. When SW_1 is open, equivalent resistance is $R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$, $R_{eq} = \frac{36\,\Omega \times 18\Omega}{36\Omega + 18\Omega}$, $R_{eq} = \frac{648}{54}$, $R_{eq} = 12\Omega$.
9. When SW_1 is closed, equivalent resistance is $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$ $1/R_{eq} = 1/36\,\Omega + 1/18\,\Omega + 1/12\Omega$, $1/R_{eq} = 1/36 + 2/18 + 3/36$, $1/R_{eq} = 6/36$, $1/R_{eq} = 1/6$, so R_{eq} is 6Ω.

QUIZ #8

1. Direct current is seldom transmitted over long distances because **alternating current** is transmitted much more efficiently.
2. In an alternating-current circuit, an individual electron moves **back** and **forth.**
3. **Positive peak**



zero volts

negative peak

4. The number of cycles occurring in one second is known as **frequency** which is expressed in **hertz.**
5. Using Ohm's law, I = E/R, so I = 10v/10Ω = **1 A.**

6. Watts = I × R, so in this circuit Watts = 110 volts × ½ amp. **55 watts** of power are being used.
7. Kirchoff's voltage law says that the sum of the voltage drops equal the supply voltage, so 50v + 30v + 20v = **100 volts.**

QUIZ #9

1. **Metal film** resistors are quite heat sensitive.
2. **1000** Ω with no more than 10% error.
3. **21000** Ω (±20%)
4. **520000** Ω (±20%)
5. **44** Ω (±20%)
6. **90** Ω (±20%)
7. **7.5** Ω (±20%)

QUIZ #10

1. A capacitor is two **conductors** separated by an **insulator.**
2. A capacitor has a **potential difference** between its plates when it's in use.
3. RC is a **time constant.**
4. 5RC is the period of time it takes for a capacitor to reach **full charge.**

QUIZ #11

1. When troubleshooting a battery-operated circuit, always **check the battery first.**
2. A **pencil eraser** is a good cleaner for plated contacts.
3. A **3300 ohm, ½ watt** resistor may be used to replace a 3300 ohm, ¼ watt resistor.
4. Always **discharge** a capacitor before testing it.
5. An ohmmeter test of a gas-filled lamp will give an "infinite ohms" reading because the ohmmeter's battery won't turn the lamp on.

QUIZ #12

1. Reliable circuits must have good **mechanical** as well as good **electrical** connections.
2. **Acid** flux will destroy electrical circuits.
3. A wattage rating tells you how much electrical energy is converted to **heat energy.**
4. Always **tin** an unplated soldering iron tip before using it.
5. A clean soldering iron tip will be **shiny.**

QUIZ #13

1. Before you tin a stranded wire, **twist** its strands together.
2. Tin only the end of stranded wire to keep the wire from becoming **stiff.**
3. PC means **printed circuit.**
4. The **conductors** on a PC board are also known as lands.
5. **Tin** the tip of your soldering iron before you put it away.



SUMMARY

Practical electricity has dealt with the use of the basic tools and instruments used in repair and measurement of electrical circuits.

The multimeter is probably the most frequently needed of all electrical measuring instruments. The multimeter usually performs the functions of ohm meter, voltmeter and ammeter. The multimeter performs these different functions by using a function selector switch and a number of scales on its meter face. The function selector and scales are seldom designed for only one ohms, volts and amps reading. Most multimeters have several scales and ranges in each measuring function.

The multimeter is the #1 troubleshooting instrument because of it versatility. For componenets outside of a circuit, the ohmmeter is the most often used multimeter function. By knowing the electrical characteristics of the component to be tested and then testing the component using the ohmmeter, bad fuses, resistors, capacitors and coils can often be spotted. The volts and amps functions of the multimeter are used primarily for in circuit tests.

Because every electrical circuit requires that the electrical components be connected both electrically and mechanically, soldering is the most often encountered means of wiring a circuit. Good soldering requires practice as well as an understanding of what good soldering is.

Tips for good soldering:

- Select the soldering iron appropriate for the job. This is usually a 25 to 30 watt iron.
- Prepare the conductors. Usually removing insulation from wires, frequently the cleaning of the conductors to be soldered, and tinning the conductors before attempting to make the final connection.
- Keeping the soldering iron clean and in proper shape. Use of a wet sponge to wipe off the tip as well as tinning the tip before putting the iron away will help.